WATER-ENERGY RELATIONSHIP

In support of the
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STAFF PAPER

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EXECUTIVE SUMMARY

The story of the development of water resources in California is a story of human ingenuity. Nowhere else is so much water moved so far to serve so many people. More than two-thirds of California's population uses water that travels amazing journeys over hundreds, even thousands, of miles, all to supply the people, fields, and industries of our state. This was made possible by engineering endeavors that are difficult to comprehend in their size and complexity; but what makes the system work is electricity: massive amounts of it. That electricity use is the primary subject of the Water-Energy Relationship paper.

Finding the answers to five key questions framed the process of the Water-Energy Relationship Study and Staff Paper. California Energy Commission and Department of Water Resources (DWR) staff members, with guidance and input from a diverse working group of energy and water industry professionals, developed the questions. Where complete answers were not possible, the process identified data gaps. This Executive Summary focuses on whether and how these questions were answered.

1. *What are the electricity requirements for water storage, statewide or regional conveyance, supply treatment, local delivery, primary end-use, and wastewater treatment and disposal?*

2. *What effects will changes in hydrologic and/or climatic conditions (that is, wet years vs. critical dry years) have on electricity supply and/or demand?*

3. *How will California's water development, treatment, and use change in the future, and how might these changes affect electricity demand?*

4. *What water use efficiency or conservation methods are or will be implemented by water agencies or service companies and how does implementing these methods impact electricity demand?*

5. *What actions can be taken to improve the effectiveness of existing water sector programs, such as conservation, efficiency and forecasting programs, to assist water management agencies to use energy more efficiently or to aid in fostering more efficient and effective use of California's water resources?*

Question 1

What are the electricity requirements for water storage, statewide or regional conveyance, supply treatment, local delivery, primary end-use, and wastewater treatment and disposal?

The total current electric demand in all these areas of the water sector is at least 26,000 gigawatt-hours (GWh) annually, which was about 10.2 percent of total energy use in 2001. That amount is evenly split between water agency use (for conveyance, treatment, distribution, and wastewater treatment and disposal) and water-related uses on the customer side of the water meter (to heat, cool, or repressurize the water once it is inside the home or business, or on the farm). Table ES-1 shows the electric energy use broken down to the lowest level of aggregation possible given the available data. The total amount of energy used for groundwater pumping in the agriculture and residential sector is unknown, but existing information shows that previously underestimated energy demand from irrigation alone could add another 6,000 GWh to the estimated total. Because the purpose of this study was to focus on electricity use in the water sector, these numbers do not include natural gas or diesel fuel energy use.

Table ES-1: Present Demand in the Water Sector

Present Demand in Water Sector?

Water Supply Includes all pumping for conveyance and distribution	*11,953 GWh*
Treatment Includes treatment to potable standards, sewage and watewater treatment, and disposal	*1,388 GWh*
End-Use	*12,482 GWh*
Irrigation Pumping	*2,269 GWh*

DATE: *6/05*
SOURCE: *California Energy Commission*

Better known is the rate of electricity use for urban water agencies. Table ES-2 shows the estimated range of energy use per gallon for the various processes involved in urban water systems. Collectively, urban water and wastewater facilities draw about 3,000 megawatts (MW) of power at peak use, with about 1,800 MW of that occurring in Southern California. Water agency electricity use varies tremendously. Agencies that get their water from the Hetch Hetchy system, for example, use no electricity for conveyance, since the water travels from the Sierra Nevada to the Bay Area by gravity. But agencies at the end of the State Water Project use nearly 9,000 kilowatt-hours (kWh) per million gallons for conveyance alone.

Table ES-2: Urban Water Agency Energy Use

Urban Water Agency Energy Use by Sector
(kWh/MG)

Conveyance:	0 - 10,000 kWh/MG
Treatment:	100 - 5,000 kWh/MG
Distribution:	0 - 1,200 kWh/MG
Wastewater pumping:	0 - 400 kWh/MG
Wastewater treatment:	1,000 - 3,500 kWh/MG
Total:	**1,100 - 20,100 kWh/MG**

DATE: *6/05*
SOURCE: *California Energy Commission*

Total electricity use in the water sector remains only an estimate, however, because huge data gaps exist in the energy requirements for irrigation in the agricultural industry, and for groundwater pumping in general. Very little data exist for groundwater pumping in the state; in the agriculture sector, what little data is available is quickly outdated because of the rapid changes in planting patterns in response to crop price dynamics. Additional research is needed in this area to reconcile these data gaps and more accurately assess electricity consumption and demand in the water sector. Please see Chapter 1 for complete information.

Question 2

What effects will changes in hydrologic and/or climatic conditions (that is, wet versus critical dry years) have on electricity supply and/or demand?

The "perfect storm" (or "non-storm") in the water sector is an extended drought. As snow and rain runoff decreases, and reservoir levels drop, surface water deliveries would likely be severely cut back. Water agencies would turn to the other options available to them: increased groundwater pumping and withdrawals from "conjunctive use fields," which are groundwater basins used to store surface water during surplus times for later withdrawal during supply shortages. Electric energy and power demand would increase dramatically during such a drought (see Question 3), and hydropower generation would also be severely curtailed, just when it is needed most.

Nearly as bad as an extended drought, from a water and energy management perspective, is a shift in precipitation patterns that result in more rain but less snow. The Sierra snowpack acts as the state's largest reservoir, holding more water than all existing reservoirs combined. More rain but less snow not only reduces the size of the snowpack, it causes the snowpack to melt and runoff earlier in the year. Water agencies cannot store all of that early run off, as they must leave enough space in the reservoirs to hold back the floods of a late-season storm. The result of such a scenario is that surface deliveries would be reduced and cut off earlier during the season, creating an almost identical effect on electricity use as would occur during extended drought. Continued study is needed to assess the possible energy effects created by drought or climate change, as well as to evaluate development of programs, technology, and management tools to address those energy effects. See Chapter 3 for a more complete discussion of the effects of drought or climate change.

Question 3

How will California's water development, treatment, and use change in the future, and how might these changes affect electricity demand?

Table ES-3 lists the range of potential increases in electricity consumption and demand in the water sector. Water agency electricity use is already growing at a faster rate than is the population, and will likely accelerate again in coming years as agencies grapple with new regulations and requirements that could roughly double urban water agency electricity use.

Table ES-3: Potential Water Sector Electricity Use Increases by 2015

Potential Water Sector Electricity Demand Increases by 2015

Cause	Increase
More Stringent Treatment	At least 1,400 GWh
Water Market Transactions	Perhaps 2,000 GWh
Conjunctive Use Pumping	1,300 MW, and 3,450 GWh
Increased Drip Irrigation	Perhaps 1,900 GWh
Recycled Water System Development	Easily 6,000 GWh
Desalination Facility Development	About 2,150 GWh
Total	**16,900 GWh**

DATE: *6/05*
SOURCE: *California Energy Commission*

New regulations and requirements that will affect electricity demand and use in the water sector include:

- **More stringent treatment standards**, likely requiring the use of increasingly finer membrane treatment systems and ultraviolet light sterilizers: Exact increase is unknown because rules will not be final until

2006. Water agencies predict treatment electricity use to roughly double, from about 1,400 GWh to about 2,800 GWh, an approximate 0.6 percent increase in present electricity use in the state (about 253,500 GWh).

- **Changes in the water market** that will increase long-distance water transactions: Generally involving transferring water to Southern California from further up the line on the California or Colorado River Aqueducts, these changes in conveyance patterns can add as much as 11,500 kWh per million gallons in electricity use for the conveyed water; total increase is difficult to predict because of rapid changes in market and precipitation patterns, but changes resulting from just one set of agreements enacted by Metropolitan Water District in 2003 caused an increase of 577 GWh. Though such transactions can actually reduce overall electricity use, for planning purposes staff recommends an assumed 2,000 GWh increase in electricity use due to water market transactions, which would be about 0.8 percent of total electricity use in the state.

- **Increased use of conjunctive use fields:** Increased pumping from these fields during drought or other surface supply curtailment would cause an immediate 350 MW increase in power demand, with the potential for an additional 1,300 MW increase by 2010 as new fields are developed; 875 MW of that would be in Southern California and 425 MW in Northern California. Total electricity consumption would vary according to use; but use of the fields for 90 days per year would be about 3,450 GWh, or about 1.4 percent of total electricity use in the state.

- **Increased use of drip irrigation** in the agriculture sector caused by shifts in crop planting patterns, and efforts to conserve water: Recent trends show that drip use may have decreased in recent years due to a 15 percent reduction in vineyard acreage, but the trend could reverse quickly due to volatility in crop pricing. Exact increases are as difficult to predict as crop prices, but one study predicts that a doubling in drip-irrigated acreage would increase electricity use by about 1,900 GWh per year, which is about 0.7 percent of total electricity use in the state.

- **Increased recycling of wastewater,** requiring additional treatment and pumping: Exact electricity impact from this development is difficult because so many agencies are involved, and the timing of their decisions to install recycled water systems is unpredictable, as is the pace of system development. Available data show that recycled water treatment roughly doubles the electricity requirements for wastewater treatment, and recycled water pumping electricity requirements can easily outstrip the treatment needs. Together, the increased pumping and treatment requirements could cause the greatest increase in electricity use in the water/wastewater sector, perhaps amounting to as much as 6,000 GWh in increased electricity use by 2010, or about 2.4 percent of total electricity use in the state.

- **Possible rapid development of desalination facilities**, first for inland brackish water sources, but also for coastal and bay seawater sources: Though relatively few desalination facilities are envisioned in the state, their intense electricity use — as much as 16,500 kWh/million gallons for seawater desalination — could result in an electricity use increase of 2,150 GWh if all present proposals are fully developed (a 0.8 percent increase in overall electricity use). However, an extended drought or shift in precipitation patterns to more rain and less snow could cause a quick jump in interest in developing such facilities.

Total Increase in Electricity Requirements

The above estimates total nearly 17,000 GWh in increased electricity use, which is about 6.7 percent of total current electricity use. All these predictions of increased electricity use are highly speculative, however, and different agencies in different parts of the state will have a different set of problems to deal with. For example, the San Diego Water Department estimates that treating uranium contamination alone could cost as much as $290 million a year for the life of the new treatment facilities, adding $1,080 per year to each customer's water bill. Other agencies have no uranium in their supplies. Many conveyance systems have zero electricity usage, but those serving the most populous areas of the state are very energy intensive; changes in the ways those systems are used could have unpredicted effects on electricity use. Conversely, increased recycling, especially, has potential to reduce long-distance conveyance energy requirements, potentially resulting in an overall reduction in water sector energy use.

Today Californians use roughly 28,000 GWh of electricity for all water-related uses. Because of the uncertainty in predicting future effects, staff recommends that 25,000 GWh be used as a conservative planning estimate of the potential increase in water sector electricity use in the next 5-10 years, with approximately two-thirds of that occurring in Southern California. Further research is needed in this area, as well as careful coordination with the agencies setting final water treatment standards, to continually refine planning assumptions for this potential electricity growth. Please see Chapter 3 for a more complete discussion of future trends in water sector electricity use.

Question 4

What water use efficiency or conservation methods are or will be implemented by water agencies or service companies, and how does implementing these methods impact electricity demand?

Fortunately, many cost-effective water conservation, efficiency, and peak-load reduction programs also provide significant energy benefits by reducing overall electricity use or shifting peak demand to off-peak periods. However, some water programs actually increase electricity use, such as conversion from gravity to drip irrigation systems. Chapter 4 provides a discussion of conservation efforts in the water sector and the barriers to their effective implementation. Appendix D of this report is an avoided-cost based analysis of present water conservation and efficiency programs to determine overall water and energy costs and benefits of known programs and rank them by those that provide the greatest overall avoided-cost benefit. This analysis shows that effective water conservation and efficiency programs can provide an entire string of benefits, including energy savings, reduced air emissions, and lowered natural gas prices.

Question 5

What actions can be taken to improve the effectiveness of existing water sector programs, such as conservation, efficiency and forecasting programs, to assist water management agencies to use energy more efficiently, or to aid in fostering more efficient and effective use of California's water resources?

While water conservation, efficiency and peak-load programs offer considerable promise for providing significant similar benefits in the energy sector, identified barriers to effective implementation are both technical and human. Primary among the barriers is a lack of institutional consistency, both in the technical assistance and in funding; second is the inflexibility in program award timelines, which often outpace water agency decision-making processes, causing missed opportunities. Another barrier in water system planning is that agencies often compare the cost of conservation programs to the average cost of water rather than to the incremental cost of developing new sources, which is much higher.

Careful consideration of technology use and design, and follow-up on the actual use by the human operators involved, are equally important. However, taking advantage of a recent high interest in electricity costs in the water sector, staff has determined that the water sector offers many opportunities to quickly implement cost-effective energy efficiency, conservation, and peak-load reduction. This is especially true for urban water treatment and distribution systems, many of which would require relatively simple modifications and additions to quickly implement peak-load reduction, providing benefit perhaps as early as this summer, but certainly by summer of 2006. Please see Chapter 4 and Appendix D for a more complete discussion of water conservation, efficiency, and peak-load reduction programs.

To overcome these identified barriers, staff is developing a single clearinghouse of information and assistance available to water agency and energy professionals, and the general public, to address energy management in the water sector. Staff intends to tap the resources of the multi-disciplined working group established for this study to guide development of this clearinghouse, and of a pilot program for providing comprehensive technical assistance and funding to water sector agencies and individuals, with the goal of providing the best overall energy and water benefit. Depending on the results of that pilot, the Energy Commission and the Department of Water Resources could jointly develop a comprehensive program to provide state-wide long-term assistance, and identify sources of funding, for conservation, efficiency, and peak-load reduction programs in the water sector, from source to end use to wastewater disposal. Please see Chapter 6 for a more complete discussion of staff's findings and suggested policy options resulting from this study.

Key Identified Findings and Research, Development and Demonstration Opportunities

Findings

1. Electricity use in the water sector could nearly double by 2015, far outpacing population growth.

2. Electricity use for groundwater pumping in general, and irrigation use specifically, is likely significantly underestimated due to large data gaps; trends for such future use are unknown.

3. Extended drought and shift in precipitation patterns to more rain and less snow would greatly increase water sector electricity use and simultaneously reduce hydropower generation.

4. Significant, cost-effective opportunities exist to reduce water sector electricity use overall through water conservation and efficiency programs, and to reduce water sector electricity peak demand with relatively simple changes to water system equipment and operations.

5. Water agencies are seldom given credit, nor are they able to secure funding, for the electricity savings that result from water conservation and efficiency efforts, and essentially no cost/benefit analysis is conducted on the overall water and energy effects of water conservation and efficiency programs.

Research, Development and Demonstration Opportunities

1. To help water professionals incorporate energy management considerations in water system design and operation, and develop electric generation facilities in their systems, Energy Commission staff intends to establish a comprehensive clearinghouse of information concerning power generation and energy conservation, efficiency, and peak-load reduction. This effort will also include information related to the potential energy requirements of new regulations, especially related to water and wastewater treatment, and development of recycled water systems. Such an effort could result in significant peak electric load reduction in the water sector as early as the summer of 2006. Partners in this effort would

include virtually all the agencies and organizations mentioned below, plus such entities as the California Department of Health Services, the Pacific Institute, the California Urban Water Conservation Council, the Natural Resources Defense Council, and the state’s universities.

2. Following development of the clearinghouse, the Energy Commission and the Department of Water Resources could consider establishing a pilot program to provide active technical support, and to identify potential sources of funding, for energy management programs in the water sector.

3. To assess future water-energy research, development and demonstration (RD&D) needs, the Energy Commission and the Department of Water Resources could build from the foundation established in the “Water and Wastewater Industry Energy, Efficiency Research Roadmap” jointly developed by the Energy Commission’s Public Interest Energy Research (PIER) program, the American Waterworks Association Research Foundation and the Water-Energy Research Foundation. PIER program should implement the roadmap suggestions when they help achieve Energy Commission's public policy objectives.

4. The Energy Commission can work with the Department of Water Resources, the California Department of Food and Agriculture, the Irrigation Training and Research Center, the Center for Irrigation Technology, the Electric Power Research Institute, the National Laboratories, and other entities to develop methods to study groundwater-related electricity use in general and irrigation use specifically.

5. Similarly, the Energy Commission can work with the state and regional water quality control boards, the California Association of Sanitation Agencies, Association of California Water Agencies, the American Waterworks Association Research Foundation, the Water Reuse Foundation, and other entities to develop methods to study current and future electricity use related to development of recycled water facilities and systems, and of desalination facilities.

6. The Energy Commission and Department of Water Resources could take advantage of the group of professionals who have participated in the Water-Energy Relationship Working Group established for this study process. This group could be very useful in future planning efforts, such as the Energy Commission’s Integrated Energy Policy Report and DWR’s Water Plan, as well as in targeted study efforts, such as in developing new electric generation facilities such as digester-gas generation and pumped-storage facilities.

INTRODUCTION

The Water-Energy Relationship (WER) Staff Paper is part of the California Energy Commission's Integrated Energy Policy Report (IEPR) proceeding, initiated to better understand the relationship between the water and energy sectors, especially electricity.[1] The IEPR Committee set a goal to work with other stakeholders to address critical issues associated with water demand and supply strategies that have energy implications. The state's growth in population places great pressure on municipalities to secure sufficient water supply to accommodate that growth. In addition, several other factors, such as water quality degradation, groundwater overdraft and aging facilities, will potentially increase the electricity needs of the water sector. Specifically, electricity demand in the water sector may grow because of:

- Increased water treatment requirements that may include the use of more energy intensive membrane treatment systems and ultraviolet light sterilizers.
- Changes in the water market and continued growth in water-poor parts of the state that will increase long-distance water transfers.
- Increased water banking in conjunctive use fields, where agencies pump surface water into aquifers during times of surplus, and pump it out during supply shortages.
- The dramatic shift in crop patterns away from row crops and towards vineyards and orchards, prompting increased use of drip irrigation.
- The decision by many communities to resolve water supply and wastewater disposal problems by recycling wastewater, requiring additional treatment and pumping.
- Additional development of desalination facilities, first for inland brackish water sources, but also for coastal and bay seawater sources.

If not coordinated and properly managed on a state-wide basis, the water sector's increased electricity demand has the potential to affect the reliability of the electric system in times of high use, when generation reserve margins are tight. Without reliable and adequate supplies of electricity, the water sector may be unable to meet the needs of its customers.

This staff report examines these issues and what can be done to address them, as well as those features of the water sector that generate electricity and possible opportunities to expand this generation. The report is meant to inform and provide technical support to decision makers, water and energy industry professionals, and the general public about the critical energy supply and

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[1] In general, water system "energy use" refers to electricity use. About 15 percent of water sector energy use is on the form of diesel fuel or natural gas, mostly for engine-powered pumps, and most of that is used in summer months. Water-related end-use applications, such as water heating, also use a significant amount of natural gas. This Staff Paper is mostly limited to discussion of electric energy use. Future efforts will include non-electrical energy use in the water sector.

demand issues inherent in the water sector. This study presents the best available information available on the energy and water links.

The process to develop this paper included two public workshops, several meetings of an ad hoc Working Group[2] formed for the study, and interviews of scores of water professionals. This outreach included two meetings with members of the Association of California Water Agencies (ACWA), which represents about 90 percent of the water agencies in the state, many of which also operate wastewater treatment facilities, and with members of the California Municipal Utilities Association.

Previous best estimates by the California Energy Commission (Energy Commission) and the Department of Water Resources (DWR) showed that the water service providers used approximately 7 percent of the electrical energy consumed in the state in order to treat and deliver fresh water to the customer and then treat and dispose of the resultant wastewater. Consumers used a similar amount of electrical energy to heat, cool and pressurize the water coming into homes, farms, or businesses for a total estimate of 15 percent of the electrical energy consumed in the state. New information examined as part of the Water-Energy Relationship study process indicates that this estimate is likely too low, and may be closer to 20 percent, mostly due to undercounting of irrigation pumping electricity use. Additional energy, primarily in the form of natural gas, is used for water-related end uses, especially for water heating.

To better understand and quantify the relationship between water and energy, the Energy Commission is funding a study through the Public Interest Energy Research (PIER) Program being conducted by the University of California at Santa Barbara and the Pacific Institute to classify and quantify all water-related energy use, in all sectors, including water supply, conveyance, treatment, distribution and wastewater, treatment and disposal. The study will also include a survey of water systems to determine the distribution of electricity use among water facilities: that is, that 10 percent of treatment plants use 100 kWh per acre-foot, 20 percent use 200 kWh per acre-foot, and so forth. This study is expected to be completed later this year, and therefore, cannot be incorporated into this paper.

Water use by the electricity generating sector is also being addressed in the Electricity Environmental Performance Report (EPR), while water use by the petroleum sector is being addressed in the Petroleum EPR, both of which are

[2] The Working Group consists of representatives from state water and energy-related government agencies, local and regional water agencies, industry organizations, environmental and citizen groups, and other key water professionals. It was established to help guide and critique this Staff Paper, but its life is expected to extend beyond the WER study process to work on other planning efforts, such as DWR's Water Plan process, and perhaps a planning effort related to optimization of pumped-storage opportunities in the state. The transcripts of all Working Group meetings on pumped-storage will be made available to the public, and will become part of the record of evidence for the 2005 Integrated Energy Policy Report.

also studies conducted by Energy Commission staff as part of the Integrated Energy Policy Report process.

Staff Paper Organization

This Water-Energy Relationship Staff Paper relies heavily on the following documents:

> Department of Water Resources' 2005 Water Plan Update, which provides an excellent picture of the water cycle in California today, as well as fully examines dozens of options for managing the state's water resources over the next 30 years (available on-line at http://www.water.ca.gov/)
>
> "Water and Wastewater Industry Energy Efficiency: A Research Roadmap," a planning document developed in a collaborative process involving the Energy Commission's Public Interest Energy Research program, American Waterworks Association Research Foundation, Water Environmental Research Foundation and other organizations (available at http://www.energy.ca.gov/pier/iaw/descriptions/500_01_040_ROADMAP.PDF)
>
> "Energy Down the Drain, The Hidden Costs of California's Water Supply," conducted jointly by the Pacific Institute and the Natural Resources Defense Council (available at http://www.nrdc.org/water/conservation/edrain/contents.asp)
>
> "Methodology for Analysis of the Energy Intensity of California's Water Systems, and an Assessment of Multiple Potential Benefits Through Integrated Water-Energy Efficiency Measures," by Robert Wilkinson for Ernest Orlando Lawrence Berkeley National Laboratory, and the California Institute for Energy Efficiency through the Environmental Studies Program at the University of California, Santa Barbara (available at http://www.es.ucsb.edu/faculty/Wilkinson_EWRPT01%20DOC.pdf)
>
> "California Agricultural Water Electrical Energy Requirements," prepared for the Energy Commission's Public Interest Energy Research Program, Energy in Agriculture Program by the Irrigation Training and Research Center at California Polytechnic University in San Luis Obispo (available at http://www.itrc.org/reports/cec/energyreq.html)

Chapter 1 provides a primer on the water cycle in California -- the sources of water, where it is stored, the conveyance systems that transport it to end users, the treatment it must receive, its end use on the customer side of the water meter, and the resultant treatment and disposal of the wastewater created. The electricity production and consumption requirements of each of those phases are also discussed. The technical details of these systems are more fully described in Appendices A and B, and excerpts of the Department of Water Resources' 2005 Water Plan Update identifying fundamental lessons, foundational actions, and recommendations concerning California's water use can be found in Appendix C.

Chapter 2 examines present and potential future development of electric generation facilities associated with water and wastewater systems, and Chapter 3 looks at trends for future electricity use in the water sector. Chapter 4, along with Appendix D, provides examples of electricity management options in the water sector, and analyzes both the water and energy effects of dozens of selected programs. Chapter 5 briefly discusses water use in the energy sector, including the petroleum production and electric generating sectors. Finally, Chapter 6 examines the data gaps that were identified during the report process, and potential means to fill them.

I. CALIFORNIA’S WATER CYCLE AND RELATED ENERGY CHARACTERISTICS

Having lived through many drought-mandated watering restrictions, most Californians are at least somewhat aware of the importance of water in their daily lives. However, most Californians are less familiar with the amount of energy necessary to treat and deliver water to their homes, farms, or businesses, or to heat, cool or re-pressurize it once it gets into their buildings or onto their farms. Every step of the water cycle, from source to use to wastewater disposal, requires electricity. That electricity costs Californians at least $2 billion per year, and this electricity use and dollar figure are expected to grow.

Geography, population distribution and climate are the main reasons for California’s extraordinary energy use: about two-thirds of the state’s population lives in the southern one-third of the state, while two-thirds of its precipitation falls on the northern one-third of the state. Rainfall amounts vary greatly throughout the state and from year to year. Snow fall is primarily in the Sierras. An elaborate system of manmade storage, treatment and conveyance structures exist to augment natural features and ensure that water is delivered where Californians need and want it.

This chapter provides a basic description of the water cycle and what is known about its electricity characteristics.

A. Raw Water Sources, Storage and Conveyance

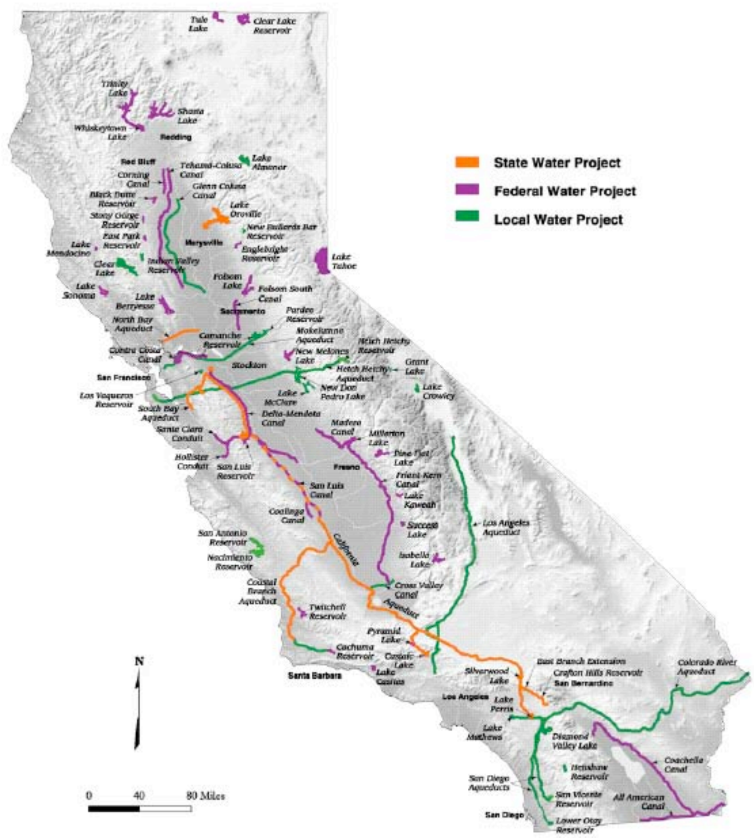
Californians collectively use about 42 million acre-feet of water (about 14 trillion gallons) in a normal year, of which some 9 million acre-feet go to the urban sector, and the balance to agriculture. (DWR 2005 Water Plan Update Volume 3, Table 1-1) The vast majority of water used in California comes from rain or snow. Rain irrigates farms and gardens directly, but also is captured as it runs off the land into drainages and reservoirs, or percolates into groundwater basins. A far greater source of water for the state, however, is the Sierra snow pack, which generally holds more water than all the state’s lakes and reservoirs put together and conveniently melts during the warmer and drier months, flowing through natural rivers and streams, through large human-made storage and conveyance systems, and recharging groundwater aquifers.

Understanding the energy implications of water use in California requires a basic knowledge of the various water systems that collect, store, and transport water supplies. These supplies can be roughly categorized as surface water or groundwater sources. These sources and the major human-made infrastructure developed to store and move their contents are briefly described below, as are two other relatively minor water supplies, recycled wastewater and desalted water. More detailed descriptions of some of the major human-made infrastructures are contained in Appendix A.

Surface Water Sources, Storage and Conveyance

Surface water resources include natural lakes and streams, and artificial reservoirs and canals or aqueducts. Most of the in-state surface water resources are fed from runoff coming from the Sierra Nevada, as well as from the Cascade Range, Klamath Mountains and Coast Range in the far northern part of the state, which runs down one of about two dozen rivers and is captured in various reservoirs. These water storage facilities serve a number of purposes, including flood control, irrigation and urban water supplies, and electricity generation (see Figure 1). California has nine major human-made surface water infrastructure projects.

Figure 1: Major Water Projects in California



Source: Department of Water Resources

Central Valley Project

Located in the northern part of the state, the Central Valley Project (CVP) is a federal flood control, power generation and water conveyance project administered and managed by the Bureau of Reclamation. The project's 20 dams and reservoirs, 39 pumping plants, 11 powerplants, and 500 miles of major canals manage nearly 9 million acre-feet of water annually, delivering water to customers from Redding to Bakersfield. The project includes storage reservoirs on the Trinity, Sacramento, American, Stanislaus, and San Joaquin Rivers, and four major canals: the Tehama-Colusa Canal, the Contra Costa Canal, the Delta-Mendota Canal, and the Friant-Kern Canal.

Of the water conveyed by the CVP, about 5 million acre-feet are delivered to farms in Northern California, and about 600,000 acre-feet are delivered to municipal and industrial users (Source: Bureau of Reclamation website http://www.usbr.gov/dataweb/html/mpcvpengdata.html)

On the energy side, the CVP is a net energy producer. The CVP's hydroelectric facilities produce about 5,600 gigawatt-hours (GWh) of electricity annually, which is considerably higher than the 1,300-1,400 GWh used by its pumping facilities. Total power production capacity is about 2,100 megawatts (MW), while total pumping demand is about 600 MW. All Central Valley Project pumping plants are served by project generation facilities.

State Water Project

The State Water Project (SWP) is a complex network of pumping and power plants, 21 major reservoirs and lakes, and more than 662 miles of canals, tunnels, and pipelines designed to move water from the Feather River basin and Lake Oroville in Northern California to users in the Central Valley and Southern California. It is the nation's largest state-built water and power development and conveyance system, and the largest electricity user in the state. The California Department of Water Resources manages the SWP to deliver water to its 29 long-term water contractors and their member water agencies; its facilities also provide flood control, recreation, and fish and wildlife enhancement.

The SWP pumping plants collectively consume about 12,200 GWh of electric energy each year, and the generating plants produce an average of about 7,600 GWh per year, for a net energy use of about 4,600 GWh. Its eight hydroelectric plants (Hyatt, Thermalito, Gianelli, Warne, Castaic, Alamo, Thermalito Diversion, Mojave, and Devil Canyon) have a total generating capacity of about 1,475 MW. However, energy use and production is highly variable, depending on hydrologic and storage conditions. For example, over the period 1990-2001, net energy use varied from a low of 3,421 GWh in 1998 (a very wet year with high hydroelectric production), to a high of 8,171 GWh in 1990, in the middle of the 1987-1992 drought. (CEC DAO California Electricity Consumption 1990-2001 Spreadsheet, A. Gough)

SWP manages its loads and generation resources to maximize off-peak pumping load and on-peak generation in order to minimize water delivery costs. The SWP's power resources portfolio also includes contracts for power purchases, sales, and exchanges. The SWP is operated as an independent bulk power entity and is interconnected with the western U.S. transmission grid. DWR dispatches the SWP's own loads and resources and coordinates its power operations through the California Independent System Operator (Cal ISO).

Colorado River Aqueduct

The Colorado River Aqueduct flows from Lake Havasu in western Arizona more than 240 miles to Los Angeles County. It includes 92 miles of tunnels, 63 miles of concrete canals, 55 miles of concrete conduits, and 144 siphons, totaling 29 miles. The project also includes five large pumping plants that lift the water a total of 1,617 feet, collectively using about 2.24 GWh of electricity per year. Though a net energy user within California, the aqueduct was constructed jointly with several federal hydroelectric projects on the Colorado River, including Hoover, Parker, and Davis Dams, totaling 2,450 MW in generating capacity and producing 5,646 GWh of electricity in 2004.

Los Angeles Aqueduct

The historical Los Angeles Aqueduct is capable of carrying 485 cubic feet of water per second more than 220 miles from the Owens Valley on the east side of the Sierra to the City of Los Angeles. A second aqueduct added in 1970 is capable of transporting 290 cubic feet per second more than 137 miles from the Haiwee Reservoir in southern Inyo County to Los Angeles. The Los Angeles Aqueduct neither consumes nor produces electric power, using only gravity to move water across the state,

Mokelumne Aqueduct

The East Bay Municipal Utility District's (EBMUD) Mokelumne Aqueduct carries water from the Pardee Reservoir on the Mokelumne River in Calaveras County 90 miles across the San Joaquin Valley through Stockton to East Bay reservoirs. EBMUD completed the first phase of the aqueduct during a supply emergency in 1929, and has since added two more aqueducts to parallel the first, delivering a total of 82 billion gallons to its retail customers last year (EBMUD 2004 Annual Report), which collectively provided service to 1.3 million people. EBMUD's system is gravity fed to the Bay Area, requiring no pumping; with its 23.6 MW powerhouse at Pardee Dam, EBMUD's conveyance system is a net energy producer.

Hetch Hetchy Regional Water System

The Hetch Hetchy System consists of more than 280 miles of pipelines, 60 miles of tunnels, 11 reservoirs, five pump stations, and two water treatment plants. It provides water to 2.4 million people in San Francisco, Santa Clara, Alameda, and San Mateo counties. About 85 percent of that water comes from Sierra Nevada snowmelt stored in the Hetch Hetchy reservoir, on the Tuolumne River in Yosemite National Park. Gravity moves the Hetch Hetchy water 160 miles to the San Francisco Bay Area through very large pipes (penstocks) buried beneath the Central Valley floor. The remaining 15 percent of the system's water comes from local rain runoff captured in reservoirs in San Mateo and Alameda Counties. The entire system delivers an average of approximately 260 million gallons of water per day to its customers. Pumping is only needed after the water reaches the Bay Area and is stored in local reservoirs.

The Hetch Hetchy system also includes three major powerhouses that produce power from water released from three reservoirs: Hetch Hetchy, Lake Eleanor, and Lake Lloyd (also called Cherry Lake). Lake Eleanor water drains into Cherry Lake, which then drains through 165 MW Holm Powerhouse as it flows into the Tuolumne River via Cherry Creek. Hetch Hetchy water flows through the 117.6 MW Kirkwood and 100 MW Mocassin Powerhouses. The power system delivers an average of 1.7 GWh of electricity annually to the City and County of San Francisco, the Modesto and Turlock Irrigation Districts and tenants at the San Francisco International Airport.

All American Canal System
Completed in 1940, the All-American Canal System carries water from the Colorado River westward along the U.S./Mexico border to irrigate fields in the Imperial Valley in the southeastern corner of California. It is partially administered by the Bureau of Reclamation and partially by the Imperial Irrigation District (IID). The All-American system consists of the Imperial Diversion Dam and Desilting Works, the 80-mile All-American Canal, and the 123-mile Coachella Canal. The system irrigates about 530,000 acres in the Imperial Valley and 78,530 acres in the Coachella Valley; it also supplies water to the federal Yuma Project, which serves farms in Arizona and California near the City of Yuma.

The All-American system includes both generating stations and pumping plants. IID operates nine powerplants along the canal, totaling about 57 MW in generating capacity. Included among those is the 7 MW Pilot Know plant, which has the capability of producing power from water in the canal and returns it to the Colorado River near the Mexican border to meet international treaty requirements. IID is by far the largest user of canal water, feeding into a labyrinth of canals and drains totaling more than 3,100 miles in length. The distribution system consists of 1,472 miles of laterals, while the drainage system consists of about 112 miles of closed drains and 1,341 miles of open drains. The project also includes a small storage feature, the Senator Wash Reservoir and Pumping-Generating Plant, which can store water during times of surplus and discharge it back into the canal when needed.

Coachella Canal
Branching off the All American Canal about 12 miles west of Yuma is the Coachella Canal, which carries water northwesterly for 123 miles to the Coachella Valley County Water District's distribution system, which administers the canal. The distribution system is largely underground, consisting of gravity flow concrete pipelines, with a few small pumping plants serving the higher areas. The network of laterals totals about 495 miles in length. The Bureau of Reclamation recently completed a project to line most of the All-American and

Coachella canals, which previously lost more than 70,000 acre-feet of water each year that soaked into the sandy soils beneath the unlined canals.

Energy Use and Production of Surface Water

Electricity Requirements for Conveyance

On the whole, large amounts of energy are needed to carry water across long distances and over great elevation to reach the urban centers of Southern California; however, the actual electricity needed for conveyance of a given water shipment varies from essentially zero to more than 9,000 kilowatt-hours (kWh) per million gallons.

Staff estimates that, on average in California, about 100 kWh of electric energy is needed to convey one million gallons from its source to the treatment plant. Irrigation districts in the North can divert water directly into their canal systems using gravity rather than electricity. On the other hand, water conveyed the entire length of the State Water Project consumed a net total of 6,034 GWh of electricity in 2001. About 6,000 kWh/million gallons is required to pump water through the Colorado River Aqueduct to urban Southern California. (See Table 1, Energy Consumption for Various Metropolitan Water District [MWD] Sources) (Metropolitan Water District 1996)

Conveyance energy use also varies with precipitation, with considerably more energy expended during wet years as the surplus water is transported into storage.

Table 1: Energy Consumption for Various MWD Sources

Water Sector Energy Use

For West Basin MWD (kWh/AF)	
Imported Water	
SWP	3,044
Colorado River	2,044
Groundwater	
Replenished with Recycled Water	500
Replenished with SWP Water	3,500
Replenished with CR Water	2,500
Recycled Water	490 - 1,280
SW Desalination (estimated)	4,425

DATE: 6/05
SOURCE: California Energy Commission

Staff estimates the state consumes approximately 12,000 GWh each year for all pumping related to water conveyance, storage, treatment, and distribution, and for wastewater treatment and disposal. Staff does not have data available to disaggregate that amount to just conveyance. However, the Energy Commission through its PIER program is funding a study of water-related energy use underway by UC Santa Barbara and the Pacific Institute that is attempting to disaggregate all water-related energy use on both sides of the customer water meter.

Hydropower Production and Consumption

On average, about 12 percent of the electricity delivered to customers in the state comes from in-state hydroelectric production. The amount is highly variable depending on hydrological conditions. The electric system in the state is designed to take advantage of the hydro generation available during the spring runoff. From a system dispatch point of view, one of the worst things that can happen is to watch water spill over the top of dams, bypassing the powerhouse turbines. When dam levels approach these “spill conditions,” hydropower can become very cheap. However, hydropower is very valuable later in the year, if available, when it can provide readily dispatchable production during peak load conditions on hot summer days. Unlike large thermal power plants, which are generally limited in their ability to quickly ramp up power production, hydro plants can ramp up very quickly to meet peak load needs.

Installed in-state large hydroelectric capacity totals about 8,470 MW (not including pumped-storage units), with about 1,350 MW of that classified as small hydro; but because of various environmental and operational restrictions, total reliable capacity generally hovers around 6,000 MW during the spring runoff. Looking at recent years, in-state large hydro project production was about 29,667 GWh in 2003, supplying about 11.5 percent of the electricity consumed in the state, while small hydro plants (which are classified as renewable plants, while the larger plants are not) produced 4,669 GWh. Another 9,560 GWh of out-of-state hydropower was imported that year, meaning a total of about 17 percent of the electricity consumed in the state that year came from water power. In the wetter year of 2002, hydropower supplied 19.3 percent of California’s electric needs. (2CEC, EAO 2003 and 2004) Over the period 1983 to 2001, California hydropower production varied from a low of about 21,500 GWh in 1992, at the end of a four-year drought, to a high of 59,000 GWh in 1983.

Hydropower facilities in California are licensed by the Federal Energy Regulatory Commission (FERC). In California, 44 projects totaling about 5,000 MW are scheduled for relicensing by 2015. On a capacity basis, this is 37 percent of the state’s entire hydropower system, including many of the large projects owned by PG&E and Southern California Edison. Historically, FERC hydro licenses were issued for 30 to 50-year time periods, but that was prior to the adoption of current environmental regulations. Relicensing provides important opportunities – once in a generation opportunities – to bring older licenses and facilities into conformance with modern scientific and regulatory standards.

Conveyance System Hydropower Production
Surface water is unique from other water sources in that its conveyance offers some opportunity to produce energy, not only to consume it. Many large federal and state-owned hydropower facilities supply power for the massive pumping stations built to move water through the long-distance conveyance projects in the state. And many of the conveyance projects include generating stations that take advantage of the kinetic energy in the water headed downhill in enclosed pipes and penstocks, such as on the downhill sides of the Tehachapi Mountains in the State Water Project and in Metropolitan Water District's system. Water agencies in general have looked for opportunities to install such "conduit" hydroelectric facilities in their conveyance and distribution systems, usually where their systems have pressure relief or other types of energy dissipation devices installed.

Pumped-Storage
Many of the conveyance projects also have pumped-storage capability, where operators can pump water to a higher reservoir during off-peak times, and let it drain down through powerhouses to a lower reservoir when power is needed. A handful of large stand-alone pumped storage projects (that is, those not part of or connected to a conveyance system) also are found in the state. Present pumped-storage generating capacity in the state is about 2,760 MW (Presentation to CEC Workshop, Hydropower System - Energy and Environment, May 22, 2003, by Mary Jo Thomas, Independent System Operator)

Major pumped-storage facilities in the state include: Pacific Gas & Electric's 1,212 MW Helms Pumped Storage Project; the Department of Water Resources' 644 MW Edward C. Hyatt, 126 MW Thermalito, and 424 MW W.R. Gianelli Pumped-Storage Projects; Los Angeles Department of Water and Power's 1,331 MW Castaic Pumped Storage Project, which takes advantage of SWP and CVP deliveries into Castaic Lake; and Southern California Edison's 200 MW Eastwood project.

Pumped storage methods include both typical on-stream conventional, and modular off-stream technologies. The major differences between the two are that Modular Pumped-Storage (MPS) systems are much smaller, use artificially created water systems instead of natural waterways or watersheds, and can use modular pre-engineered equipment. MPS reservoirs are charged only once, either with groundwater or even municipal wastewater, and then only need makeup water to compensate for evaporative losses.

Pumped-storage can be a valuable tool in managing the electric system, as noted by the Energy Commission in its 2004 IEPR Update: "While supplies are tight during peak periods, the state has more than adequate amounts of power in the low load periods, especially at night. California utilities and generators have some options for shifting power supplies from off-peak to on-peak periods through the use of pumped-storage facilities. While limited, these options would not only reduce the number of power plants needed to meet daytime peaks, but could also increase the overall efficiency of the generating sector by increasing baseload operations and decreasing load-following and peaking operations. This would reduce natural gas use and air emissions as well.” The report recommended that “California establish a joint planning effort to use existing pumped-storage facilities in the state more fully.”

Groundwater

Groundwater supplies about 30 percent of the state’s water needs on average, but as much as 60 percent during severe drought. Several hundred million acre-feet of water are stored in 450 groundwater aquifers that underlie the state, compared to approximately 45 million acre-feet in California's 1,200 surface water reservoirs (ACWA Water Facts Website). These aquifers are recharged either naturally or artificially. Natural recharge generally consists of runoff that percolates into the soil, or migration of surface water through a lake or streambed. Almost all of the 450 groundwater aquifers in the state are in decline or overdrafted, forcing users of that water to pump from greater and greater depths, using greater amounts of energy in the process.

Artificial recharge is increasingly being used in the state to address a wide variety of issues, including the storage of water. It can also be effective in slowing or stopping land subsidence -- the physical lowering of the land surface caused by loss of hydrostatic pressure below the surface due to overpumping of groundwater -- which has lowered surfaces as much as 30 feet in the western San Joaquin Valley. And it can be used to establish a hydraulic barrier to prevent infiltration of saltwater into overdrafted freshwater aquifers near the ocean or bays. However, if not properly sited, artificial recharge can increase the potential for liquefaction during a seismic event.

The process of artificially storing groundwater for future withdrawal is called Aquifer Storage and Recovery (ASR). Closely related to ASR as water resource management practices are "conjunctive use" and "artificial recharge," and the terms are often used interchangeably. Agencies around the state are storing water in aquifers for daily and seasonal use and for emergency use during drought. In general, surplus water available during the spring runoff is pumped into wells or allowed to percolate into aquifers from specific ponds and lakes; wells are used to withdraw the water when needed. (USGS 2005, Introduction to Aquifer Storage and Recovery, http://ca.water.usgs.gov/issues/6.html) However, underground storage entails some limitations compared to surface storage, both on a water basis and an electricity basis. For example, the Metropolitan Water District estimates that at least 600,000 acre-feet of underground storage is needed to produce 200,000 acre-feet [3] of water per year during a drought, and the water must be pumped out, at significant electricity cost.

[3] Water moves very slowly in conjunctive use fields, as little as 2 meters per year, limiting the amount of water that can be withdrawn in a given year. By comparison, most surface water

Many agencies are considering such storage as a main water management tool, and development of new ASR facilities is likely to grow at a rapid rate in coming years (ASR Forum Website, http://www.asrforum.com/index2.html). ASR systems can usually meet water management needs at less than half the capital cost of other water supply alternatives. When compared to construction of water treatment plants and surface reservoirs, construction of new ASR facilities can cost up to 90 percent less. (ACWA Workshop 4/14/05, and ASR Forum Website)

Electricity Requirements for Groundwater Pumping
Groundwater pumping remains unquantified in the water world, both in terms of how much water is pumped, and the amount of electricity used to pump it. The Department of Water Resources in its Water Plan process conducts yearly water balance estimates, in which total water supplies are compared to total water use. But DWR's estimates generally do not account for the completely unknown factors of natural recharge and subsurface inflow and outflow. For these reasons, plus the absence of data on farm and residential groundwater pumping, estimates of the total amount of groundwater pumping remain educated guesses.

In its most recent 2005 Water Plan Update, DWR highlighted the water balance in three years, 1998, 2000, and 2001, when precipitation was 171, 97, and 72 percent of normal, respectively. In all three years, aquifer storage fell, even during the surplus year of 1998. (DWR 2005 Volume 3, Table 1-2) In wet years, surplus water is used to replenish surface storage, rather than aquifer storage.

When total estimated water use exceeds total estimated supply, groundwater pumping generally makes up the difference (Working Group Meeting 3/15/05). But groundwater pumping is occurring even beyond making up for precipitation shortfalls. For instance, some areas rely on groundwater for their supplies even when precipitation provides surface water in other areas. Groundwater continues to be pumped out faster than it can be replaced, even in wet years, and the declining aquifer levels mean that the water must be pumped from greater and greater depths, requiring more energy.

Even more difficult to estimate is the total amount of electricity used to pump that groundwater. Electric use for groundwater pumping by municipal agencies is well known because those data are all recorded. Groundwater pumping from so-called "adjudicated" aquifers, which are those under the Main San Gabriel, Central, West Coast, Chino and Upper Los Angeles River Area basins, is also well-known, as agencies in those areas maintain excellent pumping records as part of a comprehensive management plan. Pumping from these basins totals 500,000 acre-feet or more of annual water supply. What is not well known is the total amount of groundwater pumped by the hundreds of thousands of groundwater wells that serve residences, farms, businesses, and small water

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storage is immediately available, limited only by minimum pool levels, and the capacity of the conveyance system that moves it to where it is needed.

systems in non-adjudicated basins because the electricity used to pump the water is often not separated from all the other electricity uses monitored by those meters and because those wells seldom are monitored for total flow.

Factors that affect the amount of electricity used for irrigation pumping are both human and mechanical. In the agriculture sector, the farmer determines the amount needed to irrigate a given crop; but the amount of electrical energy used is often a factor of the cost of electric service against the cost of diesel fuel. Whether or not the farmer decides to use electricity, the energy use depends on the depth from which the water must be pumped, the pressure sustained in the discharge of the pump, the efficiency of the pump and motor, and other variables.

The Energy Commission estimate of irrigation pumping energy use was the one area of disagreement during the WER Staff Paper process. Specifically, Energy Commission staff has estimated that the total amount of electricity used for irrigation pumping by all agricultural-classified customers in the state combined was 2,269 GWh in 2001.[4] This number is based on information reported by electric utilities around the state, which comes from meter data, and it is reported in different categories dependent on customer classification. However, these categories are independent of utility rates, and Energy Commission and utility staff acknowledge errors in the classifications,[5] which likely has led to data gaps concerning irrigation electricity use.

The Irrigation Training and Research Center (ITRC) at California Polytechnic State University in San Luis Obispo in 2003 released an innovative and provocative study concluding that irrigation electricity use in the state totaled 10,160 GWh in 2003. The study, based on GIS and other real-world data, began by determining the total amount of acreage in production in the state and then used assumptions and other data to calculate electricity demand. (ITRC Report No. R 03-006, California Agricultural Water Electrical Energy Requirements - Final Report, Funded by PIER, California Energy Commission, October 2003, www.itrc.org/reports/cec/energyreq.html)

ITRC agrees that the data submitted to the Energy Commission by utilities regarding the categorization of electricity use in agriculture (crop production, animal production, irrigation, and water supply) are inaccurate, with agricultural irrigation use often undercounted or counted in the wrong categories. ITRC and Energy Commission staff also identified inconsistent accounting of irrigation electricity use in the two estimates. For instance, ITRC's estimate includes irrigation district groundwater pumping, while staff's does not. ITRC's estimate also includes the agricultural portion of water conveyed long distances, such as through the State Water Project; Energy Commission staff track this electricity

[4] This would account for just under 1 percent of the total electricity use in the state in 2001, which was about 253,500 GWh

[5] For instance, some customers could have as much as 30 percent of their metered electricity devoted to pumping, but not be classified as such.

use in a separate category (part of the 6,349 GWh of net SWP electricity use in 2001).

ITRC noted that a study conducted nearly 30 years ago by the University of California at Davis, which staff has reviewed, concluded that agricultural irrigation then accounted for nearly 7,100 GWh of electric use in the state. Interestingly, that study found that more than half of that amount was consumed in just one basin, comprising the drainages of the Kings and Kern Rivers in the southern portion of the San Joaquin Valley. Factors cited for this were that the basin had the largest number of irrigated acres, the deepest wells, a high percentage of irrigated acres served from those deep wells, and also a relatively high electricity requirement to deliver surface water to that area. (Knutson, G.D., R.G. Curley, E.B. Roberts, R.M. Hagan, and V. Cervinka. 1977. Pumping Energy Requirements for Irrigation In California, Div. of Agricultural Sciences, University of California, Special Publication 3215.).

In addition, since that 1977 study, the total number of acres irrigated with pressurized water (drip, micro, or spray) increased from 1.4 million acres to 4.2 million acres, while average pump efficiency fell from 59.5 percent to just 52 percent. When these factors were used to correct the 1977 study for 2003 conditions, the total calculated electricity use is consistent with ITRC's 2003 estimate of electricity use for agriculture irrigation. (Memorandum on Comparison of Ag-Water Energy Estimates from the ITRC and the April 8 CEC analysis of Utility Records, from Charles Burt and Dan Howes of ITRC to Pramod Kulkarni and Ricardo Amon of CEC, April 28, 2005).

The irrigated acreage statistics cited by ITRC coincide with the Department of Water Resources' recent estimates (DWR 2005 Water Plan Update); and in fact, considerable evidence exists showing that the amount of energy used to produce that water likely increased considerably during that time.

While staff acknowledges that its estimate for agriculture-related irrigation electricity use is likely too low and recommends additional research of the subject, it is important to note that determining the actual present amount is less important than determining the likely change in that amount in coming years. The electricity supply/demand balance in rural areas could be affected if electricity use in the agriculture sector grows significantly in coming years. For example, a drought in the Sacramento or San Joaquin Valleys would cause increased groundwater pumping, which could have a significant impact on the electricity grid, especially in the southern San Joaquin Valley.

Recycled Water

The fastest growing new source of water in the state is not a new source at all, but rather is recycled water from wastewater systems. Faced with increasingly stringent requirements related to the disposal of wastewater and limited water supplies, many agencies are installing additional treatment facilities that can purify wastewater to the point where it can be substituted for use of fresh water in many applications, such as for power plant cooling or landscape irrigation.

More than 300 water recycling plants are in operation in California. California's first water recycling project began in 1929 when the City of Pomona began providing treated wastewater from its municipal sewage treatment plant for landscape irrigation; the city still provides this service, and is able to use 100 percent of its recycled wastewater by doing so. The first plant built solely for recycling and reuse was constructed in 1932 in San Francisco. The Irvine Ranch Water District in Orange County has recycled water for nearly 30 years and currently supplies recycled water to high-rise office buildings for use in toilets and urinals.

Recycled water is also used to replenish depleted groundwater aquifers. For example, the Orange County Water District and Orange County Sanitation District's new Groundwater Replenishment System is designed to increase current water reuse by taking treated wastewater that is currently being released into the ocean and purifying it through microfiltration, reverse osmosis, and ultraviolet light with hydrogen peroxide advanced oxidation treatment. The purified water will be injected into a seawater barrier and pumped to percolation ponds to seep into deep aquifers and blend with Orange County's other sources of groundwater. The Groundwater Replenishment System is projected to begin delivery of purified water in 2007, with potential for future expansion as needed (California Water Plan Update 2005 Volume 3 – Regional Reports, Chapter 5. South Coast Hydrologic Region).

Energy requirements for recycled water systems are discussed further in this chapter under "Wastewater, Collection, Treatment, and Disposal."

Desalted Water

Desalination involves removal of salts and dissolved solids from seawater or brackish water. Most desalination processes are based either on thermal distillation or membrane filtration technologies, both of which are very energy intensive. In addition to the removal of minerals, these processes remove most biological or organic chemical compounds.

Most of the currently operating desalination plants that produce potable water utilize brackish groundwater rather than seawater as the feedwater. These include groundwater desalting plants currently operated by the Santa Ana Water Project Authority, Chino Basin Desalting Authority, City of Corona, Eastern Municipal Water District, Irvine Ranch Water District, the City of Oceanside, West Basin MWD, the Sweetwater Authority, and the Alameda County Water District. Brackish groundwater desalting delivers about 100,000 acre-feet per year of water today, and an additional 150,000 acre-feet per year could be produced if currently planned projects are developed. (California Water Plan Update 2005 Volume 4 – Reference Guide, California Water Quality in 2004)

The largest planned desalination facility in the state is Poseidon Resources' proposed plant in Carlsbad, which would intake seawater through the ocean-front Encina Power Plant, owned by Cabrillo Power (a joint venture of Dynegy and NRG Energy). The City of Carlsbad has contracted with the San Diego County Water Authority to buy drinking water produced at the $270 million plant. Under the deal, Carlsbad would purchase 5,000 acre-feet of the treated water -- about 25 percent of the city's total water need -- from the water authority at about $710 per acre-foot. The city currently pays the water authority around $566 per acre-foot for its water, all of which is imported from sources such as the Colorado River. The project is awaiting approval by the California Department of Health Services, the Regional Water Quality Control Board and the California Coastal Commission. Poseidon hopes to break ground on the plant in the fall of 2006 and begin operations by 2010. (Pisor 2005)

High costs have limited development of desalination facilities in California, but costs are declining, making seawater and brackish groundwater more viable as water supply resources. Because it is one of the very few options for increasing present water supplies, water agencies may build and operate many such facilities in the future. Desalination facilities make more economic sense in areas that have high energy costs for their water supplies, such as in the urban areas of Southern California.

Electricity Requirements for Desalination

The approximately 60 present desalination facilities in the state produce about 220,000 acre-feet of water per year. About 30 of these are municipal facilities that produce about 80,000 acre-feet of drinking water per year; the remainder are industrial facilities, including one at the Diablo Canyon Nuclear Power Plant, which is one of the larger desalination plants in the state. Electricity costs are the most significant component of the cost of operating desalination plants, with seawater desalination being considerably more energy intensive per acre-foot than brackish water desalination. At present, brackish water desalination facilities in the state outnumber seawater facilities by more than three to one.

Based on the information from existing facilities, brackish water desalination uses on the order 3,900-9,750 kWh/million gallons, depending on the source water quality, plant capacity, and technology used.[6] Seawater desalination is even more energy intensive, using 9,780-16,500 kWh/million gallons, depending on the salinity and the temperature of the source water. (Taskforce, 2003) Most desalination plants operate continuously, so this energy is used during all seasons, and at all times of the day. Current plants are operating 90 percent of the time, with downtimes only for maintenance.

[6] Disposal of salt brine is becoming an increasingly difficult problem for inland plants, and future such plants may be required to use zero-liquid discharge systems, which would require additional electricity to operate.

Based on the figures above, existing desalination facilities are using on the order of 370 to 890 GWh per year, which is only about three-tenths of 1 percent of total electricity use in the state, even at the high end estimate.

B. Treatment

Treatment of potable (drinkable) water in California generally consists of several stages, including coagulation, flocculation, sedimentation, filtration, and disinfection, not all of which are used in every treatment facility. Because of the wide variation in water supply quality, facility age, and local requirements, very few treatment facilities are identical, making discussion of the “average” water treatment facility problematic. Water systems vary tremendously in the state, from those that serve millions of customers to those that serve a handful. Some have water supplies of such high incoming quality that very little treatment is required, especially those relying primarily on high Sierra surface reservoirs (such as Hetch-Hetchy) and groundwater. Others receive water with very high amounts of sediment and contaminants such as arsenic and nitrates, requiring more treatment and using more electricity in the process. Treatment systems are also having to remove more and more refined chemicals found in primary water sources, such as solvents and other hazardous compounds that have contaminated aquifers beneath industrial and manufacturing facilities (for example, perchlorate contamination in many well fields of Southern California communities). Technologies found in water treatment systems are described in Appendix B.

Water Treatment Electricity Costs

Based on electric and water meter data, an estimated 250 kWh/million gallons is used by the average treatment facility in the state. Again, this number is highly variable. Systems that use only highly pure Hetch Hetchy water need only treat with small amounts of chloramine as it enters the distribution system to ensure biological contaminants do not develop in the far reaches of the system; electricity use for such a system would be on the order of just a few kWh per million gallons for a small pump to inject the chlorine into the water as it enters the distribution system. Water districts that take water directly from local runoff or aqueducts require more extensive treatment to meet regulatory standards and taste-and-odor preferences of customers. Other treatment plants have unique requirements, such as removal of industrial chemicals from well water. In general, additional treatment entails additional energy use.

Electric loads at treatment plants consist primarily of pump motors, but also include air blowers, injection equipment, controls, lighting, and in some cases, ultraviolet light disinfection. The Energy Commission Demand Office estimates that a total of about 1,400 GWh of electricity is used in the average year in all treatment facilities, including water and wastewater facilities. This is based on electric and water meter data, plus assumptions from engineering handbooks and other sources as to electricity use of certain equipment. Because the meter data is not reported in separate categories, it cannot be disaggregated to separate water from wastewater treatment.

Despite extensive data searches, staff found only a few studies that attempted to determine exact electricity use for water and wastewater treatment facilities. One of the most comprehensive and innovative studies came out of an effort in Sonoma County to address greenhouse gas emissions, which included study of energy use by municipal facilities, including the county's wholesale water agency, the Sonoma County Water Agency, and all its municipal system water customers. The County Water Agency provides domestic water to 540,000 domestic water users in Sonoma, Marin, and Mendocino Counties. Its only source of water is the highly variable flow of the Russian River, and storage at two reservoirs on tributaries of the Russian, Lake Sonoma near Healdsburg and Lake Mendocino near Ukiah.

The EPA has listed the Russian River as impaired because of dissolved solids and nutrients. To avoid these impairment issues, and to comply with Endangered Species Act limitations on stream withdrawals, many of the County Water Agency's municipal customers mix the river water with about equal amounts of groundwater, which is generally less costly.

The Sonoma County Water Agency required nearly 2,600 kWh/million gallons to pump and treat water from the river over the period of April 2000 to September 2002. Pumping costs were essentially linear throughout the year (that is, the electricity use per million gallon rate was essentially constant) except for spikes in January and February, when large amounts of surplus water were transferred to storage in reservoirs, especially in Marin County.

The Climate Protection Campaign's study focused on programs that provide the greatest reductions in greenhouse gas production per dollar spent, and though reducing pumping energy use provided considerable benefits, the study concluded that even larger reductions in emissions would occur through water conservation. (Rosenblum 2003)

While Sonoma County Water Agency represents the upper end of the electricity use spectrum for water conveyance, treatment and distribution, the East Bay Municipal Utility District is an example of an agency on the lower end of that spectrum. The district gets 95 percent of its water from the Mokelumne River, delivered by gravity through the Mokelumne Aqueduct. The Mokelumne water is relatively high quality at its source, requiring little treatment; and the District's treatment facilities are located high in the East Bay Hills, using the elevation to help pressurize its distribution system. Because of these factors, EBMUD's electricity use is approximately 150 kWh/million gallons for conveyance, and 275 kWh/million gallons for treatment. (EBMUD 2000 and Navigant Consulting 2004)

To date, the Energy Commission's electricity demand estimates have focused on energy, rather than capacity, which is why capacity needs are considerably less well-known than energy demand. However, ACWA estimates that the state's water and wastewater treatment facilities collectively draw about 3,000 MW at peak, with 1,800 MW of that occurring in Southern California Edison territory, and the rest geographically distributed throughout the state more or less in proportion with population. This number seems reasonable given the estimated energy use rates at such facilities, and the nature of their operations. It is important to note that water treatment facilities have their peak water demand, and peak electric demand, during the hot summer months, when overall electricity use also peaks. Wastewater flows and energy use also increase during such times, though their peaks are actually during winter storms.

C. Distribution

Once treated to potable standards, the water must be distributed to customers, generally through a network of storage tanks, pipes, and pumps. Distribution offers many challenges in that the water must be kept moving and under pressure in order to minimize corrosion and biological contamination. Storage tanks and water mainlines must be flushed periodically to prevent oxidation and to control biofilms. (AWAARF 2000). Even the farthest reaches of the network must be kept under adequate pressure and constantly flushed, because low pressure and low flow allow microbes to flourish (ACWA Workshop April 14, 2005).

Electricity Use for Distribution

The most energy-intensive portion of an agency's water service is generally in distribution, consisting almost entirely of pump motors. On average, staff estimates that city water agencies use about 1,150 kWh/million gallons of electricity just to deliver water from the treatment plant to the customer. Electricity use for water system distribution is also highly variable, dependent upon the topography of the area served, the total pipe length of the system, total water use in the system, the age of the system (older systems are often leaky and partially clogged with corrosion, requiring additional pumping energy to overcome the losses and higher head pressure, and may be undersized even without the corrosion), and other factors. Larger systems must install booster pumps at various points to ensure the farthest reaches remain pressurized.

Cities with hilly terrains can use hilltop tanks both as storage and to provide pressure into the distribution system; San Francisco is perhaps the best example of this, with virtually all of its customers served from hilltop tanks. But the water must first be pumped up to the tank, often several hundred feet in elevation. In addition, though water agencies loathe wasting water and energy, they often must flush water from the tanks to prevent microbial contamination of the tank, and then fill them up once again through the pumping station. For example, this flushing often accounts for the bulk of electricity use in EBMUD's distribution system, which because of the high elevation of its treatment facilities is only about 644 kWh/million gallons.

Rapid change in use, during sporting events or heat waves, for example, is also a challenge in the engineering and operation of a distribution system and has a significant effect on electricity use in the system (as well as for water supply treatment and wastewater treatment and disposal). More and more water utilities are implementing demand forecasting tools to reduce the energy costs required for these variations in distribution demands. (Water and Wastewater Industry Energy Efficiency: A Research Roadmap, PIER/AwwaRF, WERA, 2004)

D. Uses: Residential, Industrial, Commercial, Agricultural

Once the water is delivered, customers use it in a variety of applications. Residential uses include personal hygiene (shower, bath, sink), dish and clothes washing, toilets, landscape irrigation, chilled water and ice in refrigerators, and swimming pools and spas. Residential energy uses related to these activities include water treatment (filtering and softening), heating (natural gas or electric water heaters), hot water circulation loops, cooling (icemakers and chilled water systems for HVAC and chilled drinking water), circulation (Jacuzzi pumps, for example), and in some cases, groundwater pumping of private wells.

Commercial and industrial applications include all those found in residences, plus hundreds more. Some of the more energy intensive applications related to commercial or industrial water use include high-rise supplemental pressurization to serve upper floors, steam ovens and tables, car and truck washes, process hot water and steam, process chilling, equipment cooling (X-ray machines, for example), and cooling towers. Agricultural water use can also be energy intensive, requiring extensive pumping and, in some cases, treatment; but it can also be essentially energy free, using gravity alone to flow the water onto fields.

End Use Electricity Consumption

End use applications use more energy than any other part of the water cycle. In fact, energy used for water end-use applications -- that is, the energy that goes into the water on the customer side of the water meter -- is estimated to be roughly equal to the amount of energy expended to convey, store, treat, and deliver that water to the customer, as well as to treat and dispose of the resultant wastewater. Using utility reported data and other information related to customer water and electricity use, staff determined that Californians expend about 12,500 GWh of electricity per year to heat, cool, or pressurize water once it gets into their homes and businesses. The PIER-funded study of water-related energy use in the state underway by UC Santa Barbara and the Pacific Institute is also attempting to disaggregate energy use for all categories of water end use in the residential, commercial, agricultural, and industrial sectors.

E. Wastewater Collection, Treatment and Disposal

Other than water devoted to landscape irrigation, or lost through evaporation (such as in cooling towers and other processes), almost all the water entering homes and businesses in California eventually leaves as wastewater. During rainy weather, a considerable amount of runoff also ends up in wastewater systems, greatly increasing treatment costs. Even those communities that do their best to keep stormwater out of their sewer systems will see nearly double the flow during a winter storm event than during the dry summer months. This "infiltration/inflow" of stormwater into the sewer system has on occasion forced many communities to discharge raw or minimally treated wastewater directly into local waters. (California Stormwater BMP Handbook, The California Stormwater Quality Association, January 2003, http://www.casqa.org/)

Wastewater treatment is similar in nature to freshwater treatment. But most wastewater treatment systems have the additional step of using biological reactors that use bacteria to break down the waste. Wastewater pumps are inherently more inefficient because they must pump both liquids and solids, and necessarily must have greater clearances between the pump impeller and the casing, allowing much of the pumped water to return to the intake plenum. Industrial wastewater is often treated at the industrial facility before it is allowed to enter the sewer system. Energy use in a wastewater system is primarily from use of very large electric pumps and blowers and use of natural gas to heat the anaerobic digesters.

Digester biogas (approximately 60 percent methane and 40 percent CO_2) is produced by anaerobic bacteria. The gas can be collected and used to fuel a power plant, usually powered by an internal combustion engine. Waste heat recovered from the engine can be used to heat the digesters. The power produced can be used to power the facility itself or sold into the grid.

The number of water and wastewater treatment techniques, and combinations of techniques, is expected to increase with time as more complex contaminants are discovered and regulated. The number of systems employing these techniques will also likely continue to increase as communities take advantage of a multi-billion dollar revolving loan fund created by Congress in the 1990s to help water systems, especially those serving small and disadvantaged communities, upgrade or install new treatment facilities.

Most wastewater treatment facilities in the state treat their effluent to a secondary standard, making it possible to recycle this water, expanding their available water supplies. Health regulations governing the use of recycled water specify whether secondary or tertiary treatment is required, depending on the intended use. For example, when the water will be used in power plant cooling towers, it must be treated to tertiary levels. When recycled water will be used for golf course irrigation, only secondary treatment is required. The use of recycled water is on the rise. In some cases, agencies have installed separate recycled water distribution systems parallel to their potable water systems for such uses as landscape irrigation and toilet flushing. However, recycled water supply presently exceeds demand and delivery infrastructure, meaning much of it is ultimately discharged to a lake, river, bay, or the ocean. (ACWA Workshop, 4/14/05)

Electricity Demands for Wastewater Treatment and Disposal

Wastewater consumes electricity in three stages: transport to the facility, treatment, and disposal/recycle. The first stage, transporting from the customer to the wastewater treatment facility, requires about 150 kWh/million gallons of electricity on average to pump the water, depending on topography, system size and age. When they have a choice, agencies prefer to place water treatment facilities above their customers, and the wastewater treatment facilities below, to harness the pull of gravity where possible, and to place water intakes above wastewater outfalls on rivers.

The average wastewater treatment facility uses about 1,050 kWh/million gallons to treat the waste to the point it can be disposed of, which generally includes the pumping of the water to its final destination, usually draining to a stream, lake, bay or ocean, or spreading onto a field to recharge an aquifer. This amount often varies during the season, depending upon the degree of stormwater infiltration, and the turbidity in that stormwater.

Additional electricity is required if the wastewater is recycled -- not only for the additional treatment required, but also for the pumping energy needed to move the water to its final application, such as landscape irrigation, or power plant cooling. The Metropolitan Water District estimates that the wastewater facilities in its service territory consume between 1,470 to 3,840 kWh/million gallons to treat wastewater to recycled water standards (April 8 IEPR Workshop). Though predicting the growth of recycled water systems is difficult, the Department of Water Resources predicts a doubling of wastewater recycling by 2010 (Bulletin 160, volume 2, chapter 16, page 16-4).

Sonoma County’s largest wastewater facility, the Laguna Wastewater Treatment Plant, operated by the City of Santa Rosa, had a peak inflow of nearly a billion gallons per month in January and February of 2000 and 2002, while average inflow in summer months was just over half that amount (Rosenblum 2003, Figure 7). Its wastewater treatment electricity use is proportional to these flows, and therefore is nearly twice as high in winter months as in summer months. Sonoma County found that the electricity required to pump the recycled water to the end user nearly doubled the total electricity demand in its wastewater sector and also has shifted the system’s peak electricity use from winter to summer.

Pumping energy for irrigation-related recycled water in Sonoma County is essentially zero during the winter months, when the treated wastewater is discharged to the river and accumulated in storage reservoirs, but is essentially equal to the treatment electricity use in the summer. Therefore, total electricity use at the plant, including both wastewater treatment and recycled water pumping, follows a summer peak/winter valley pattern. (Rosenblum 2004, Figure 8). For example, in February 2001, treatment electricity use was 2,500 kWh/million gallons, while reclaimed water pumping electricity use was zero. In May of that year, treatment required about 1,500 kWh/million gallons, and reclaimed water pumping required an equal amount, for a total electricity use for that month of about 3,000 kWh/million gallons.

Throughout the entire study period, the Laguna plant used between 2,300 and 3,472 kWh/million gallons for treatment. Electricity use tended toward the lower level of that band for most of the period and spiked during the winter of 2001. The Laguna plant cogenerates about 40 percent of its annual electricity for treatment using 50 percent natural gas and 50 percent biogas. In February-May 2001, natural gas prices spiked, making it more expensive to cogenerate electricity than to purchase it, so the Laguna plant cogenerated only when biogas was available.

Though recycled water pumping has considerable potential for increasing electricity demand in the wastewater sector, it is important to note that in many instances, this pumping merely replaces other distribution pumping. Sonoma County is the exception, as most of the recycled water is being used for agriculture that previously otherwise would use surface water resources, and therefore overall energy use in the County's water sector increased with the development of its recycled water systems. But in many other urban communities, recycled water is replacing potable water use. However, those communities that have varied elevations usually place their water treatment facilities at higher elevations, and wastewater at lower elevations. Pumping recycled water up from the wastewater plant would use more energy per gallon pumped than the distribution pumping in these communities.

II. POTENTIAL FOR NEW GENERATION

Hydropower

Opportunities for new hydropower dam and storage projects are extremely limited in California for a variety of reasons. Most economically viable sites have already been developed, but even where suitable sites exist, development is limited by lack of availability of unallocated water rights, environmental protection measures (such as Wild and Scenic Rivers, Endangered Species, and Wilderness Area designations), and strong political opposition. New development requires very long timeframes to plan the project, prepare appropriate environmental documents, obtain a license from FERC, and construct the project. However, opportunities for incremental development, such as adding or improving generation facilities attached to existing dams, water conveyance facilities, and powerhouses, remain an option for increasing hydropower production in California.

A 1998 Idaho National Engineering and Environmental Laboratory report concluded that California has potential to develop 10,391 MW of new hydroelectric generation nameplate capacity, producing about 3,390 MW of reliable capacity. The laboratory identified 763 potential sites in California; of those, 463 are undeveloped sites (3,384 MW nameplate), 274 are sites with dams but no powerhouses (4,812 MW nameplate), and 26 are sites with undersized powerhouses (1,745 MW). The vast majority of the identified sites are on waterways, along an arc stretching northward along the west side of the Sierra and then westward to the Trinity River drainage, but a few are on human-made systems, such as the California Aqueduct. The report gave no estimate of cost of development. (U.S. Hydropower Resource Assessment, California, October 1998, INEEL, http://hydropower.id.doe.gov/resourceassessment/ca/ca.pdf)

Water system conduit hydropower facilities are generally considered easier to license, and they likely would meet the criteria to receive above-market Supplemental Energy Payments under the Renewables Portfolio Standard program. Under these criteria, a new small hydropower project is eligible only if:

- it was placed in service on or after September 12, 2002;
- it has less than 30 MW total installed capacity at the site; and
- it does not require a new or increased appropriation or diversion of
- water.

The 1998 hydropower resource assessment concentrated mainly on impoundments and natural waterways, and an analysis of the project site data in it reveals that nearly all of the opportunities outlined in the assessment would fail to meet one or more of the Renewables Portfolio Standard eligibility criteria, closing the door on Supplemental Energy Payments. In the near term, eligibility for these payments is expected to be the primary driver of renewables development. Without changes in the law or the definition of “appropriation or diversion,” it seems unlikely that most of the capacity identified by the 1998 assessment would be developed in the near term.

Hydropower opportunities in existing canals and pipelines (post-2002) appear to be eligible for Supplemental Energy Payments under the Renewables Portfolio Standard, as long as water appropriations or diversions are not increased in the process. A recent PIER-sponsored survey of water agencies concluded that water agencies could develop approximately 255 MW of installed conduit hydropower capacity, capable of providing 231 MW of coincident peak power, and generating 1,131 GWh annually. That amount was evenly split among municipal and irrigation district systems. (California Small Hydropower and Ocean Wave Energy Resources, Mike Kane, CEC PIER, April 2005, http://www.energy.ca.gov/2005publications/CEC-500-2005-074/CEC-500-2005-074.PDF)

Use of free-flow hydropower systems -- those that require no dam or penstock, but rather harness the current in free-flowing streams and canals -- also show some promise for water system electric generation development. These include small paddle-wheel or water turbine generators, the latter looking like underwater wind farms. A New York University study of free-flow hydropower potential estimated U.S. capacity at 12,500 MW at 120 riverine sites. The Idaho National Engineering and Environmental Laboratory is considerably more bullish, estimating a potential range of 21,400 MW to 170,000 MW for riverine sites (Water Energy Resources of the United States with Emphasis on Low Head/Low Power Resources, DOE/ID-11111, April 2004). Several demonstration projects testing this technology are underway, but none have reached commercialization. One recently announced project is Verdant Power’s 25 kW free-flow hydropower demonstration project in the East River of New York, which has received funding from the New York State Energy Research and Development Authority.

Pumped-Storage

Pumped-storage is another area of potential growth in coming years. In general, pumped-storage involves use of two reservoirs or tanks, with a pumping/generating unit in between that can pump water from the lower reservoir to the higher one during off-peak times, and then generate power when water is released from the upper to lower reservoir. It is generally considered the only commercially viable method for storing electricity, and is increasingly being considered as a method to store renewable energy, especially windpower, since renewable generation is often not available when needed, and conversely is often available when not needed. (Characteristics and Technologies for Long- vs Short-term Energy Storage, DOE Energy Storage Systems Program, Susan M. Schoenung, Sandia National Laboratory, March 2001, http://www.prod.sandia.gov/cgi-bin/techlib/access-control.pl/2001/010765.pdf).

One new pumped-storage project in the planning stage is the Lake Elsinore Advanced Pumped Storage Project (LEAPS), proposed by Elsinore Valley Municipal Water District and the Nevada Hydro Company. If approved and constructed, the LEAPS project would pump water at night from Lake Elsinore, located in Western Riverside County on the I-15 corridor, to a new upper reservoir (Morrell Canyon) with a 180-foot-high main dam and a storage volume of 5,760 acre-feet. When needed, the water could be released back to the lake through a 500 MW powerhouse. (EVMD Website, 2005) The Water District filed for a license for the project in February 2004 (FERC License No. 11858).

Anther potential project is the Sacramento Municipal Utility District's (SMUD) proposed Iowa Hill Pumped Storage Development, which would become part of SMUD's 688 MW Upper American River Project (UARP). SMUD reportedly will soon file to renew the license for the UARP at the Federal Energy Regulatory Commission (License No. P-2101), including the Iowa Hill development. SMUD is proposing to develop a 400 MW pumped storage generating facility using the UARP's existing Slab Creek Reservoir as the lower reservoir and a new reservoir on the top of Iowa Hill with a storage capacity between 2,100 and 6,400 acre feet. Estimated construction cost is $300-400 million, which would be about $750 to $1,000 per installed kW of generating capacity; total cost of operation would depend upon the spread of on-peak versus off-peak power prices. (SMUD Website, 2005) The US Bureau of Reclamation is also exploring several pumped-storage options as part of a study of increasing water storage in the Upper San Joaquin River Basin (USBOR Website 2005a)

As with any dam or reservoir, development of new pumped-storage facilities faces major challenges. Some of the issues associated with conventional hydroelectric power generation and typical on-stream pumped hydroelectric storage facilities include:

- Water resources impacts (hydroelectric facilities may change stream flows, reservoir surface area, the amount of groundwater recharge, and water temperature, turbidity and oxygen content).
- Biological impacts such as the possible displacement of terrestrial habitat with a new lake environment, alteration of fish migration patterns, and other impacts on aquatic life due to changes in water quality and quantity.
- Possible damage to, or inundation of, archaeological, cultural or historic sites (primarily if a reservoir is created).
- Changes in visual quality.
- Possible loss of scenic or wilderness resources.
- Increase in potential for land-slides and erosion.
- Recreational resource impacts/benefits.

Another possibility for developing new pumped-storage projects, however, is to use two existing reservoirs or lakes and connect them with new pipelines or penstocks for pumping and generating operations. A U.S. Department of Energy study identified dozens such reservoir pairs in California, requiring construction of an average of about 10 miles of pipeline to connect the two. Based on on-peak and off-peak pricing in 2000, the study predicts that about 1,800 MW of new pumped-storage could be obtained for $1,600 per kW or less, and perhaps as much as 2,300 MW for as little as $1,200/kW. The study notes that this storage could be used to increase the value of renewable energy projects by providing "a substantial cushion to cover periods of low power output." (Lamont 2004) Even at the lower rate, that cost, totaling more than $2 billion, is significantly higher than the cost to develop new gas-fired resources; but the higher capital cost would be offset somewhat by lower operating costs. Though such development avoids construction of new reservoirs and the associated political and environmental difficulties, it still involves construction of large pipelines through difficult terrain on protected lands, which could, for instance, require significant expense for endangered species habitat loss mitigation.

Because of the costs associated with new pumped-storage facilities using existing or new reservoirs, development of modular pumped storage (MPS) appears to have greater potential in the near future. MPS systems are not dependent on natural waterways and watersheds and can be sited in areas that avoid many of the issues described above. In fact, they are generally purposely sited to avoid sensitive areas in order to avoid the regulatory and operational complexity often associated with conventional pumped hydroelectric storage facilities. MPS systems can also be added to existing water systems wherever the necessary elevation difference exists. They could also be developed in such places as abandoned mine sites, taking advantage of elevation differences and storage created by mine shafts and open pits. If less than 30 MW in capacity, these types of pumped-storage facilities can also qualify for Supplemental Energy Payments under the Renewables Portfolio Standard. (Aspen 2004)

Biogas

Another option for developing generation in the water sector is to increase use of digester gas technology at wastewater treatment plants, most of which use some form of anaerobic digestion, which produce "biogas" consisting of methane (CH_4), carbon dioxide (CO_2), and other trace gases. The biogas can be used to generate electricity and heat. Both forms of energy are useful at plants using anaerobic digestion, as the digesters must be heated to between 30-60°C. A total of about 242 sewage wastewater treatment plants serve the cities of California. About 38 MW of electrical power is generated from 10 existing sewage wastewater treatment plants, and another 12 utilize biogas to produce hot water or heat the digester (CEC Powerplant Database 2005).

Four basic technologies exist for the utilization of biogas.

1. Medium-Btu gas use

   Medium-Btu biogas can be used in a number of ways. Typically, after condensate and particulate removal, the biogas is compressed, cooled, dehydrated and then transported by pipeline to a nearby location or burned on-site in boilers or burners. Minor modifications are required to natural-gas-fired-burners when biogas is used because of its lower heating value.

2. Generation of electric power using reciprocating engines, gas turbines, steam turbines, microturbine, and fuel cells

Most existing biogas plants in the state generate electricity for on-site use using a reciprocating engine, steam turbine, or gas turbine. The biogas generally must be processed to remove condensate and particulates prior to use in an engine or turbine. Steam generation microturbines as small as 30 kW are feasible, though such technology has not been commercialized. High costs associated with biogas clean up are also an important issue for potential biogas applications for fuel cell technology.

3. Injection into an existing natural gas pipeline

Biogas can be upgraded into high-Btu gas and injected into a natural gas pipeline. As compared with other power generation alternatives, the capital cost for sale of upgraded pipeline quality gas is high because of treatment required to remove CO2 and impurities, and operating costs are higher because of the need to compress the gas to conform to pipeline pressure at the interconnect point.

4. Conversion to other chemical forms

Biogas can be converted to other chemicals, such as methanol, ammonia, or urea. Of these three options, the most economically feasible is conversion to methanol, which can be used as a transportation fuel. Converting high methane content gas to methanol requires removal of water vapor and carbon dioxide, and high compression, where it is reformed and catalytically converted to methanol. This tends to be an expensive process, which results in about a 67 percent loss of available energy.

Biogas Ingenuity

One of the more innovative applications of biogas energy is operated by the Inland Empire Utilities Agency (IEUA), which serves the Inland Empire area on the border of Riverside and San Bernardino Counties. IEUA has three biogas generating plants in its territory, all connected by pipelines that take the gas from IEUA's wastewater facilities, which together process 65 million gallons of wastewater per day into recycled water. What makes the IEUA system different is that it also collects biogas from several nearby dairies, mixes it with natural gas to ensure a high heating value, and produces about 4.3 MW of power and substantial thermal energy at three cogeneration facilities. One of these facilities also provides power and heat to IEUA's 9 million gallons per day (mgd) brackish water desalination plant, which it expects to expand to 25 mgd by 2010.

IEUA's biogas power production is expected to continue to grow as it adds another 15 mgd wastewater treatment plant next year, and it plans to develop another 10 MW in renewable biogas generating capacity with a centralized biodigester that will take dairy waste, green and food residuals (generally used to make compost) and biosolids, and produce biogas for power generation, and compost. It is also considering using excess biogas to market hot water to industrial customers.

Energy Commission staff estimates that at least 36 MW of generation can be developed at the 220 sewage wastewater plants that do not have biogas energy production. Of those, 168 sewage treatment plants have potential of less than 200 kW. However, when combined with other potential biogas sources such as dairies or food waste facilities, biogas power production could significantly increase.

Solar Power

Finally, many water agencies have considerable potential for installation of solar panels on rooftops and other structures, as well as on unused land. Many agencies are already installing such devices, and such installations are likely to increase as they become eligible for Supplemental Energy Payments under the Renewables Portfolio Standard. IEUA, for example, has installed solar panels on its new headquarters, which was designed to reduce energy use by 90 percent and water use by 70 percent compared to its previous building. IEUA expects its headquarters will be completely energy independent by next year. (Davis 2005)

Another water agency installing solar facilities is the Semitropic Water Storage District. Semitropic is one of many groundwater storage facilities in Kern County, taking advantage of its location between the California Aqueduct and the Friant-Kern Canal and the local aquifers that are suitable for aquifer storage and recovery. It stores water delivered from the two canals for customers from the Santa Clara Valley to San Diego. The water is generally stored in wet winter months and withdrawn in drier summer months.

Semitropic has installed several energy production facilities, including its own 12 kilovolt (kV) distribution system and four natural gas fueled internal combustion engine power plants, totaling 4 MW, to serve its 16 surface and 44 groundwater pumping stations. It is currently not running these plants, however, because it can buy power on the market more cheaply than it can produce it. Semitropic this spring completed installation of a 1 MW solar facility, which is expected to provide peaking power for local pump loads. (Boschman 2005)

Barriers and Potential Solutions to Water Sector Power Facility Development

In addition to some of the barriers to development of traditional hydroelectric and pumped-storage projects just described, barriers to developing conduit hydroelectric plants relate primarily to four factors:

- The inability to transmit the generated power to the owners' loads, which are generally located far away from potential conduit generating sites.[7]
- The difficulty in finding customers willing to sign long-term contracts to purchase such power.
- The expense of obtaining a license for such a facility.
- The fact that most would be less than 100 kW in size and would not qualify for Supplemental Energy Payments under the Renewables Portfolio Standard.

Biogas facilities are generally located adjacent to the wastewater treatment facility and therefore can at least provide self-generation for the facility, such as the generators at the four IEUA wastewater facilities, the output of which is used entirely for wastewater treatment. These facilities also lend themselves well to cogeneration, providing heating energy for the digesters. But these facilities tend to be small, often less than 100 kW in capacity for smaller treatment facilities and therefore do not meet eligibility requirements for Supplemental Energy Payments under the Renewables Portfolio Standard. They also require the owner to secure air emission offsets to obtain an air permit for the facility, since the digester gas fuel produces air emissions, substantially increasing the cost of development in many air basins.

Solar power development at water sector facilities appears to have significant potential in the next 10 years, as agencies take advantage of Supplemental Energy Payments under the Renewables Portfolio Standard. Most water agencies in the state have considerably larger amounts of land than needed for their facilities, providing a buffer between other land uses, and many agencies interviewed as part of this study expressed interest in developing solar panel facilities on their vacant lands. About 10 acres of land is needed to install a 1 MW solar power facility, depending upon the intensity of solar energy at the site.

Even when transmission is available to move the power out of a water agency's conduit hydropower, biogas or solar facility, the water professionals interviewed for this paper expressed frustration in their limited ability to wheel their self-generated power to their various facilities. Water and wastewater systems often are fed by several electric meters (as many as seven for a water treatment plant), and present rules do not allow aggregation of the load within a single facility, much less with the loads of other facilities in the water agency's service territory. Because they generally pay more to purchase power from their local utilities than they would to produce power from their own facilities, they would prefer to be able to wheel their own self-generated power to serve their own loads, and avoid utility purchases, rather than try to find buyers on the open market. (ACWA Conference, 4/14/05; IEPR WER Workshop Transcripts) Similar cost and infrastructure barriers affect direct sales of biogas into natural gas pipelines,

[7] Conduit hydropower facilities are generally located on the "downhill" side of the system, usually long distances from the pumping stations on the "uphill" part of the system.

which is limited by the costs of upgrading to pipeline specifications and of connecting the agricultural or wastewater treatment facilities into the pipeline.

To help overcome these barriers, and others, Energy Commission and DWR staff, in concert with the WER Working Group, are working to develop a comprehensive program for assisting water agencies in addressing energy use management in the design, construction, and operation of their systems. This will include efforts to save both water and energy, to shift water use and electric load off-peak, and to develop their own electric power generation potential. It will also include efforts to secure long-term resources to provide technical assistance and funding of cost-effective programs addressing water-related energy management. Staff intends to include utilities in this effort, and will encourage joint utility-water agency cooperation to address these issues.

As suggested by Martha Davis of IEUA, energy utilities could partner with water agencies to optimize development of their renewable energy potential, first to offset their own loads and then potentially to also become net exporters of renewables and help energy utilities meet Renewables Portfolio Standard goals and achieve other environmental benefits, including greenhouse gas reductions.(Davis 2005)

III. POTENTIAL EFFECTS OF FUTURE CHANGES

This chapter discusses the trends for electricity use in the water sector over the next 10 years. Factors affecting electricity demand related to water use include population growth, potential climate change, drought, water market changes, conservation and efficiency efforts, technology development, and new regulatory requirements. The estimated overall effect on energy use from these changes is summarized in Table 2, and discussed below.

Table 2: Potential Water Sector Electricity Demand Increases by 2015

Potential Water Sector Electricity Demand Increases by 2015

Cause	Increase
More Stringent Treatment	At least 1,400 GWh
Water Market Transactions	Perhaps 2,000 GWh
Conjunctive Use Pumping	1,300 MW, and 3,450 GWh
Increased Drip Irrigation	Perhaps 1,900 GWh
Recycled Water System Development	Easily 6,000 GWh
Desalination Facility Development	About 2,150 GWh
Total	**16,900 GWh**

DATE: 6/05
SOURCE: *California Energy Commission*

A. Drought and Climate Change

An extended drought is the “perfect storm” (or “non-storm”) of the water world. Surface water deliveries during past droughts have dropped to less than half of average year deliveries, forcing water users to rely much more on groundwater pumping, and emergency conservation measures. During drought, electricity use increases not only because of increased groundwater pumping, but also because that water must be pumped up from greater and greater depths as aquifer levels fall. Periods of drought would also significantly increase pumping from existing and future conjunctive use fields, as agencies tap the water they’ve been storing during times of plenty, and persistent drought could spark rapid development of desalination facilities.

A change in the patterns of rain and snow falls could also have significant effects on electricity use as well. Modeling of climate change scenarios that result in more rain but less snow show that, even when total precipitation is near normal levels, the spring runoff occurs much earlier in the year, and surface deliveries are cut off or greatly reduced earlier in the summer, in a pattern similar to what would occur during drought. Mitigating this effect to some degree, perhaps, would be a potential reduction in conveyance energy use because more local runoff would be available in Southern California.

As part of this study, Energy Commission and DWR staff worked closely with the Association of California Water Agencies (ACWA) to gather data and information concerning expected future electricity demand and use in the water sector. ACWA conducted a survey of its members, which revealed significant potential for load growth in the water sector, even without the effects of climate change or an extended drought. The survey results also generally coincide with the Irrigation Training and Research Center's (ITRC's) report on energy requirements in the agriculture sector, which includes modeling of climate change scenarios, as well as of market changes, shifts in crop irrigation patterns, increased desalination of agricultural drains, fuel changes, and groundwater banking withdrawals.

ACWA's survey concluded that drought would result in an immediate electricity demand increase of about 350 MW in the water sector, as water agencies begin to pump from existing ASR/conjunctive use fields that are seldom tapped during more normal years, other than for occasional testing purposes. Water agencies in Southern California alone collectively withdraw about 2.5 million acre-feet of water per year from about 34 groundwater conjunctive use fields; but a 2005 study by the Association of Groundwater Agencies estimates at least 21.5 million acre-feet of additional water could be stored and used in Southern California groundwater basins (California Water Plan Update 2005 Volume 3 – Regional Reports, Chapter 5. South Coast Hydrologic Region). Northern California agencies such as East Bay Municipal Utility District, the Santa Clara Valley Water District, the Alameda County Water District, and the Cities of Roseville, Pleasanton, and Livermore also use ASR systems. (2005 Water Plan Update)

More significant, however, was the potential for new conjunctive use demand from projects in the planning stage. The ACWA survey revealed that its members are actively considering development of new conjunctive use fields that would increase demand by 1,300 MW statewide, with 875 MW of that in Southern California and 425 MW in Northern California. Combined with the increased desalination that members predicts will occur during reduced surface deliveries (see desalination discussion), the ACWA study concluded that demand in the water sector could easily increase by 2,150 MW by 2010 (and perhaps sooner), just to deal with reduced surface water deliveries (ACWA IEPR Testimony 2005).

From another perspective, ITRC's study, which focuses on electricity use rather than peak demand, concluded that, if just the three largest groundwater storage facilities in Kern County were to begin pumping their reserves at maximum capacity, electricity use could increase by 302 GWh per year. Actual electricity use is likely to be somewhat lower, however, as the study predicts that the storage districts could not maintain the maximum theoretical pumping over time because of aquifer limitations. (ITRC 2003)

The ITRC study predicted that increased groundwater pumping by irrigation districts when surface deliveries are reduced would raise electricity use by 246 GWh per year. On-farm groundwater pumping would also likely increase significantly when surface water deliveries are reduced. The ITRC study examined the likely effects of reduced surface deliveries from eight reservoirs (Friant, Buchanan, Pine Flat, Terminus, Success, Isabella, New Melones, and Don Pedro), and concluded that groundwater pumping would add another 173 GWh of electricity demand, just to compensate for the reduced deliveries from those reservoirs. The study estimated the total electricity demand increase from increased groundwater pumping due to drought or climate change would be about 420 GWh (ITRC 2003)

B. Regulatory Changes

Water Treatment Requirements

Regulatory changes mandating more-stringent water quality requirements have perhaps the most potential to increase electricity demand in the immediate future. Most of these changes will come from standards set by the US EPA in implementing the requirements of the Safe Drinking Water Act (SDWA), which was originally passed by Congress in 1974 to protect public health by regulating the nation's public drinking water supply. The law was amended in 1986 and 1996 and requires many actions to protect drinking water. SDWA authorizes US EPA to set national health-based standards for drinking water to protect against both naturally-occurring and man-made contaminants that may be found in drinking water. US EPA, states, and water systems then work together to ensure these standards are met.

Many facilities are installing new equipment to deal with specific contamination issues, such as industrial solvents like trichloroethylene (TCE) found in groundwater beneath industrial facilities. Many are also upgrading their wastewater treatment facilities to recycled water treatment levels because of more-stringent discharge requirements. And nearly all water treatment facilities will soon have to deal with new regulations concerning a myriad of emerging contaminants, as well as newly lowered regulatory limits on other compounds, such as nitrates.

The timing and likely effects of new water treatment requirements are briefly discussed below.

Perchlorate (2006):
Perchlorate is a man-made anion commonly associated with the solid salts of ammonium, potassium, and sodium, with ammonium perchlorate as the most widely used such compound. It also occurs naturally in certain highly arid environments, and can move rapidly through surface water and groundwater systems. Perchlorate interferes with iodide uptake into the thyroid gland, disrupting how the thyroid regulates metabolism, and is especially harmful to children and pregnant women. The most common way that perchlorate is ingested is through drinking contaminated water.

Recent studies have detected perchlorate in samples of lettuce and milk in California. Past ammonium perchlorate use in the state was extensive, primarily for production of military explosives and rocket propellants but also for fireworks, blasting agents, matches, lubricating oils, air bags and certain types of fertilizers. EPA has established an official new maximum reference dose of 0.0007 milligrams of perchlorate per kilogram of water per day (mg/kg/day), considered the maximum safe dosage, which may result in significant new treatment requirements as early as 2006. (USEPA Groundwater & Drinking Water website, 2005)

About 350 sources of perchlorate contamination are known in California. Some of those will likely be remediated completely, but some will require ongoing treatment. Treatment would likely consist of increased use of ion exchange, in which perchlorate ions are absorbed into resin beads, which in exchange release harmless chloride ions into the water. (ACWA 2005b) While ion exchange requires little additional pressure itself, add-ons of perchlorate treatment facilities in existing plants extend the length of the treatment train. Additional energy costs may also be incurred through clean-up in use of pump-and-treat or installation of reactive barriers that require pumping. Also, in cases where perchlorate levels require well closures, that water supply must be replaced by new wells or imported water.

Arsenic (2006):
Arsenic enters water supplies either from natural sources in rocks and minerals or from industrial and agricultural pollution. It is a byproduct of copper smelting, mining and coal burning. U.S. industries release thousands of pounds of arsenic into the environment every year. A 1999 study by the National Academy of Sciences concluded that arsenic in drinking water causes bladder, lung and skin cancer, and may cause kidney and liver cancer. The study also found that arsenic harms the central and peripheral nervous systems, as well as heart and blood vessels, and causes serious skin problems. It also may cause birth defects and reproductive problems. (National Academy of Sciences 1999) The current EPA maximum contaminant level is set at 50 parts per billion (ppb); in 2006, this limit will be lowered to 10 ppb, and California has set a public health goal of 4 parts per trillion (ppt).

About 800 known sources of arsenic contamination exist in California, most of which will require ongoing treatment of nearby waters. Treatment options include:

- Coagulation/microfiltration, where chemicals are added to the water to create coagulation of arsenic, which is then filtered through microfiltration membrane filters to remove arsenic-containing flocs.
- Iron-Based Media, where water is run through an iron-impregnated media that absorbs arsenic, which is regularly changed out.
- Ion Exchange
- Reverse Osmosis (RO), which allows direct removal of arsenic without coagulation. Of the four options, RO is the most energy intensive.

Surface Water Treatment Rules (2006):
The US EPA is set to enact a series of new regulations that may require changes in disinfection practices as early as next year. EPA is proposing the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) to reduce disease incidence associated with Cryptosporidium and other pathogenic microorganisms in drinking water that have shown resistance to chlorine treatment. This proposed regulation is intended to ensure that systems maintain microbial protection as they take action to reduce formation of disinfection byproducts. The LT2ESWTR will apply to all systems that use surface water, or that use groundwater that is under the direct influence of surface water (i.e., that are directly recharged by surface water through an injection well).

The rules are expected to affect most surface water systems, but will especially focus on those that either do not filter their incoming water or have high Cryptosporidium levels in their water source. Compliance with the rule likely will require increased filtration.

Groundwater Treatment Rules (2006):
EPA for the first time in history will require water systems to disinfect the groundwater they pump, starting next year. The effect in California is expected to be minimal, however, as most groundwater purveyors in the state already disinfect their supplies. However, some new disinfection facilities may be needed.

Uranium (ongoing):
Uranium is a naturally-occurring radioactive element that is present in the earth's crust. Uranium is found in ground and surface waters due to its natural occurrence in geological formations, and has been shown to be a carcinogenic risk. The State of California has set a maximum contaminant level (MCL) for uranium of 20 picocuries per liter, based on earlier studies of toxicity to the kidney in rabbits. More difficult to attain however is the state's Public Health Goal of 0.43 picocuries per liter of uranium in drinking water.

According to ACWA, many water systems in the state exceed this goal, and are searching for cost-effective means to control the contamination. (ACWA 2005) The best available technology to lower the level of uranium below the maximum contaminant level is RO. Other possible treatment options include ion exchange, coagulation/filtration, and lime softening, which involves adding lime to the water to raise the pH and precipitate out certain constituents. (ACWA 2005)

The San Diego Water Department, for example, has conducted extensive tests and analysis of uranium treatment options, and concluded that accurate cost estimates are difficult, if not impossible, and are highly speculative and theoretical. The city's treatment capacity is 295 million gallons per day. The Water Department estimated that installing and operating an RO treatment system at the city's three treatment plants just to treat uranium contamination would cost between $130 – $290 million/yr for the life of the system, which would add $485 to $1,080 per year to each customer's water bill. The additional treatment would also create additional costs for corrosion control because water treated by RO is more corrosive and could cause the water to exceed lead and copper regulations. (San Diego Water Department 2004)

With the finalized treatment rules still unknown, and with a lack of analysis of potential energy effects, calculating the impact on electricity demand of these new rules is problematic. However, many parties have made estimates, ranging from a low of about a 20 percent electricity increase (EPRI) to as much as a 50 percent electricity increase (ACWA Workshop) at treatment facilities. Staff estimates this would result in an increase of average electricity use to as much as 1,600 kWh/million gallons for water treatment, and that total consumption for water treatment could increase by about 1,120 GWh per year. Many of these new limits may require treatment of previously minimally or untreated groundwater supplies, particularly in rural and small communities in California's Central Valley, and therefore the increase in energy demand could be even higher. In cases where concentration levels make treatment so infeasible that wells are closed, there may also be added energy costs from conveyance of alternate supplies.

While not related to new regulation, the spread of historic plumes of contaminants will also have energy effects because of new and deeper well drilling and greater reliance on alternative water supplies. Spreading of plumes also can result in the addition of well-head treatment plants, such as for high nitrates, which are a ubiquitous drinking water problem associated with agricultural runoff and urban wastewater disposal.

Wastewater Treatment Requirements

On the wastewater side, more stringent National Pollution Discharge Elimination System (NPDES) requirements on wastewater discharge are overshadowing all other treatment requirements, pushing more and more systems to install additional treatment facilities so they can recycle their wastewater and avoid

NPDES issues. Not only does installation of such treatment equipment raise electricity requirements for treatment by about 50 percent, it also significantly raises pumping energy demand, as the recycled water must be pumped to end users. For instance, as discussed earlier, the City of Santa Rosa has seen steady increases in pumping energy use due to its expansion of its recycled water system, and it now is essentially equal to that required for wastewater treatment (SCWA 2004).

The California Department of Health Services currently does not analyze the cost of compliance with new treatment rules, and therefore makes no reference to the energy impacts of new rules. This may change in the future, however, as DHS is considering whether to incorporate such analysis into their rulemaking process (Spath 2005).

C. Market Changes

Changes in the water market also have potential to increase electricity use in the water conveyance sector. Many parties have recently signed or are considering innovative water exchanges and transfers that could change conveyance patterns considerably, and could increase electricity use in the process. The agreements take many forms. Some involve relatively complex exchanges, including transferring water rights from one party to another in exchange for some action that compensates for the transfer, such as paying for water conservation programs or land fallowing; these types of transactions generally increase electricity use because the water must be transported past its original irrigation district delivery point.

Others involve simpler exchanges, such as when entities in Northern California store water in groundwater banks in Kern County; there is no way to get that water back up north, so instead the stored water is sent on to agencies further south, while the Northern Californians take Southern California's Delta allotments. This type of transaction is generally neutral or even beneficial to conveyance electricity use, though it could increase conjunctive use pumping. For instance, Metropolitan Water District has enacted some transfers in which it increases its Colorado River Aqueduct deliveries but decreases its State Water Project deliveries, resulting in significant net electricity use reduction.

Also likely to increase in coming years are outright transactions, where one entity sells or leases its water rights to another. Areas of marginal agricultural production, for instance, are increasingly realizing they can gain more profits by selling water rather than growing and selling agricultural products. (Boxall 2005)

ITRC examined several likely and possible water market transactions in its 2003 study. One of the findings was that just one exchange agreement between Metropolitan Water District and the Palo Verde Irrigation District (PVID), in which Metropolitan would receive up to 111,000 acre-feet per year of water previously delivered to PVID, could result in up to 230 GWh of increased electricity demand if fully implemented. The increased electricity use comes from pumping Colorado River Aqueduct water past PVID's territory near Blythe, on the California/Arizona border, all the way to Metropolitan's system at the terminus of the CRA.

Metropolitan also has several programs that can result in significant changes to conveyance patterns. These programs include paying farmers to fallow their land in exchange for a payment of $120/acre-foot for the water saved, but also include simple exchanges, such as the agreement with the Coachella Valley Water District (CVWD) and the Desert Water Agency (DWA), which serve the area around Palm Springs. CVWD and DWA have rights on the State Water Project, but no means to get it without building an expensive pipeline; but Metropolitan can get Colorado River Aqueduct water to CVWD, so the parties agreed that CVWD and DWA would get some of Metropolitan's CRA water in exchange for CVWD's and DWA's SWP rights. According to one report, Metropolitan spent about $14 million under these agreements to buy water from a variety of Sacramento Valley districts in early 2003. (Farmers OK Deal to Send Water South, by Dale Kasler, Sacramento Bee, January 13, 2005)

ITRC predicted that the electricity Metropolitan needed to get the water realized from these one-year agreements in 2003 alone was about 3,850 kWh/acre-foot (about 11,150 kWh/million gallons), since all the water was pumped the entire length of the California Aqueduct. If the electricity use of groundwater banking in Kern County was included, total electricity cost would be 4,250 to 4,950 kWh/acre-foot (12,750 to 14,850 kWh/million gallons), depending on the storage district. (ITRC 2003) Based on these estimates, electricity demand just from the transfers in early 2003 amounted to a total of about 577 GWh.

D. Changes in Agricultural Use

An unprecedented shift in crop planting patterns occurred in the state in the 1990s and early 2000s away from row crops and towards orchard and vineyard crops. Virtually all newly planted and a significant portion of existing vineyards are irrigated by pressurized drip/micro or sprinkler irrigation, as opposed to the gravity-only irrigation that was formerly used. Likewise, sprinkler and drip systems now predominate for irrigating row crops in many areas of the state, such as vegetable crops along the coast and in the deserts. According to DWR, the amount of acreage irrigated by gravity systems fell from 6.5 million acres in 1990 to just 4.9 million acres in 2000, while at the same time spray-irrigated acreage rose from 2.3 million acres to 2.8 million acres, and drip-irrigated acreage rose from 800,000 acres to 1.9 million acres. (California Water Plan Update 2005).

This explosion in vine and tree planting caused some counterintuitive results. Primary among those is that not only did it dramatically increase use of pressurized drip or spray irrigation, it also increased groundwater pumping. The reason for this is at least two-fold. When converting to drip irrigation, requiring the installation of at least a booster pump to pressurize the previously used surface water supply sources (creek, canal, ditch, etc.), the farmer often realizes that it may be cheaper to use an already installed and paid-for groundwater pump on the property, which provides purer water that needs less filtering, and therefore less filter maintenance. Second, surface water must be scheduled and delivered at specific times, and is only available to the farmer when it comes down the canal; groundwater, by contrast, is available "on-demand," whenever the farmer needs it.[8]

However, according to the California Agricultural Statistics Service, which bases its statistics on extensive phone surveys of farmers, vineyard cultivation in California peaked in 2001 at just over 1 million acres, and then declined to 932,000 acres in 2002, and down to 853,000 acres in 2004 -- a 15 percent reduction in two years, likely due to a recent decline in prices for grapes and related products. (California Agricultural Statistics Service 2005) Grape prices this year have stabilized, and show some sign of perhaps increasing.

Partially offsetting this decrease in vineyard acreage, perhaps, is the increased use of drip irrigation in other crops, primarily vegetable crops, such as celery, broccoli and "process" tomatoes -- those used to make tomato paste or other canned products. Tracking such irrigation use in real time is difficult at best, making estimations of electricity use difficult. However, the ITRC study predicts that if the amount of drip irrigated acreage in California were to double, which seems possible if not likely in coming years, electricity use would increase by about 1,900 GWh per year.

Drip irrigation is attractive to tomato growers, for example, because it proved in early trials to increase yield by 20-30 percent. However, the UC Cooperative Extension is now advising those farmers to turn off their irrigation systems earlier in the season as a means of improving quality, while having a minimal effect on yield. (Linden 2004) The Extension service is also advising wine grape growers to implement "deficit irrigation," and growers are responding. Stressing the grapevine by decreasing irrigation amounts at just the right time can greatly increase the quality of the grape, improve the color, and have little effect on yields (if timed correctly, the water reduction primarily affects leaf growth on the plant, with little effect on berry growth). Deficit irrigation has proven to save between 30 percent and 50 percent of the water normally used for such vines, depending on the location of the vineyard and type of grape. (Prichard 2002)

Another factor affecting electricity use in the agriculture sector is the potential conversion of diesel-engine pumps to electric motors. More than 95 percent of the agricultural pumps in the state were powered by electric motors in 1980, but that number fell to just 80 percent by 2000 as electric rates rose. An estimated 5,700 diesel-powered pumps are now operating in the Central Valley alone. But

[8] Some water districts can deliver water on-demand, but many do not have the infrastructure to provide this level of service. However, districts throughout the state are working to improve their systems to provide this service.

now, with diesel prices soaring and air quality rules tightening, farmers are seeing incentives to consider switching to electric motors. PG&E and Southern California Edison both are planning to enact rate schedules, subject to California Public Utilities Commission (CPUC) approval, that will offer discounts to farmers switching from diesel to electric. PG&E's proposed "AGICE" (Agricultural Internal Combustion Engine) incentive program, which if approved[9] will be available to owners of pumps of 50 horsepower and above, provides a 20 percent discount over other agriculture rates, increasing at 1.5 percent per year until eliminated, and also offers an "environmental adder" that will reduce the costs to the customer of extending distribution lines to the pump. PG&E's program is capped at $27.5 million per year in total incentives, including discounts and environmental adders. (Mayers 2005)

The ITRC study on energy requirements in the agriculture sector concluded that conversion of half the existing diesel pumps to electric would increase electricity use in the agricultural sector by 863 GWh. (ITRC 2003) That study was conducted prior to the utilities' proposing incentives to convert diesel engines to electric, but considering the cap on the utility incentive program, the ITRC prediction seems a reasonable estimate of the potential impact of diesel pump conversion.

Other signs are pointing to decreased energy use in the agriculture sector, including efforts to conserve water and energy, following the example of urban agencies that now universally follow a set of Best Management Practices (BMPs) in managing their systems. Some irrigation districts have signed on to a program sponsored by the Department of Water Resources that require implementation of Efficient Water Management Practices (EWMPs) addressing energy management. (Efficient Water Management Practices by Agricultural Water Suppliers in California, Memorandum of Understanding, January 1, 1999). That effort was prompted by the Agricultural Water Suppliers Efficient Water Management Practices Act of 1990. However, unlike urban water systems, where water conservation also brings energy conservation, agricultural water conservation can often lead to increased energy requirements. Reuse of tailwater, for example, requires installation of an additional pumps, and drip and microspray irrigation need significantly more electricity than other irrigation methods. Some of these uses, however, such as reuse of tailwater, could have a benefit by avoiding long-distance conveyance energy use.

Utilities and agencies are also addressing agricultural energy use through several energy efficiency programs. A good example is the Agricultural Pumping Efficiency Program (APEP) run by the Center for Irrigation Technology, which is part of the California Agricultural Technology Institute at the College of Agricultural Sciences and Technology, California State University at Fresno. The program gets funding from the Public Goods Charge on utility bills, and provides free pump efficiency evaluations for farmers and irrigation districts served by the

[9] The CPUC may rule on these programs in June 2005.

state’s four largest investor-owned utilities. Since 2002 the program has resulted in at least 15 GWh of savings from approximately 350 pump retrofit/repair projects. An earlier program, the Ag Peak Load Reduction Program, funded by legislation enacted during the 2000-2001 energy crisis, resulted in 71 GWh in savings from 438 pump retrofit/repair projects. (Canessa 2005)

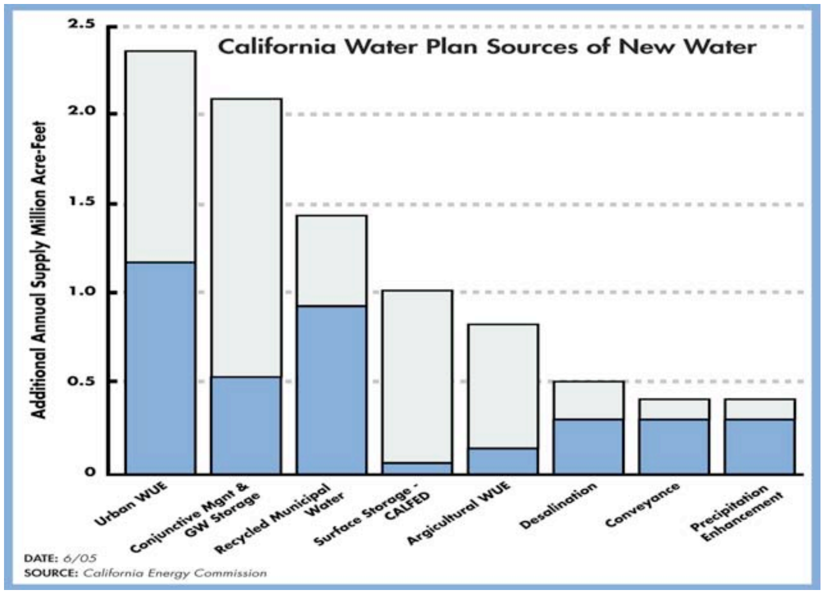
Taken altogether, when considering all the factors above, no definite conclusion can be drawn concerning the future trend of energy use in the agricultural sector. Continued surveillance of water use in the agricultural sector is advised because crop planting patterns can change as rapidly as the markets for certain products change. Spikes in the prices for crops dependent on pressurized irrigation will lead to increased planting of these crops, and increased energy use, increasing volatility in many commodity prices, and increased foreign trade will continue to be a confounding factor when trying to predict energy use in agriculture.

But perhaps an even more critical factor is continued follow-up of energy use in the agriculture sector, at every level, to ensure efficiencies are realized over time. For example, increasing the efficiency of a pump does no good if the farmer keeps running it for the same length of time, since power demand (along with flow rates) actually increases following impeller adjustment or overhaul; savings only come if the pump lifts the same amount of water as before but is operating fewer hours because of the increase in efficiency. Deficit irrigation strategies also must be monitored closely to ensure water use is optimized, and does not result in long-term stress to the plant.

E. Urban Growth, Recycled Water and Desalination

Though California’s population is expected to continue growing at a rate of about 2.2 percent per year, total water use in the urban sector is expected to remain approximately flat in coming years, as it has for the past two decades. Continued water conservation and efficiency efforts are expected to negate the increased demand created by growth, and are expected to be the primary source of new water. (See Figure 2, California Water Plan Sources of New Water) The reason for this is simple: other than desalination, and recycling wastewater, both of which are expensive options, there is essentially zero potential for securing significant new water sources in the state. Some cities, realizing they have limited ability to meet the water demand of growth-related development, such as new subdivisions, are requiring developers to secure at least twice their expected water demand through conservation, efficiency or other actions, before building can begin.

Figure 2: California Water Plan Sources of New Water



Source: 2005 Water Plan Update Bulletin 160-05 Highlights

Many cities are installing additional treatment facilities in their wastewater systems for various reasons, and thus are increasingly using their recycled wastewater to meet local demands. Some cities are even considering installing completely new distribution systems, paralleling the ones they already have, so recycled water could be used for residential landscape irrigation and in commercial buildings for toilet flushing and other non-contact applications. This growth in electricity use could be concentrated in certain areas experiencing growth rates above the state average, placing high demand on local infrastructure. For instance, the Inland Empire Utilities Agency, serving the fastest growing part of the state, predicts its peak load will grow from the present 9 MW to 25 MW in 2010. Part of that growth is attributed to a projected increase in electricity requirements caused by wastewater treatment and increased recycled water pumping. (Davis 2005)

Desalination is another option that many cities are considering for meeting future water demand, and the potential development of such facilities has prompted the state to consider the impacts of such development. Assembly Bill 2717 (Chapter 957, Statute of 2002) directed the Department of Water Resources to report to the Legislature on the potential opportunities and impediments to using seawater and brackish water desalination, and to examine what role the state should play in furthering the uses of desalination technology. DWR's resultant report, released in 2003 with input from a Water Desalination Task Force representing 27 organizations, concluded that significant opportunities exist for desalination to provide potable water to meet California's water demand, to relieve drought conditions, to replace and restore groundwater, and to provide a source of water for river and stream ecosystem restoration. (DWR/Water Desalination Task Force 2003)

The 2003 report cited plans to develop an additional 30 to 35 brackish groundwater desalting plants, which could produce nearly 290,000 acre-feet per year, and 19 seawater and estuarine desalination facilities that could generate about 240,000 acre feet per year (See Figures 3 and 4).

Figure 3: Seawater Desalination

Seawater Desalination

	In Operation		In Design and Construction		Planned or Projected	
Data Source	Number of Plants	Capacity (Acre feet/Year)	Number of Plants	Capacity (Acre feet/Year)	Number of Plants	Capacity (Acre feet/Year)
Task Force (2003)	16	4,600			19	240,000
California Water Plan Update (DWR, 2005)	6	1,440	1	50	6	187,100
ACWA	12	2,700			20	250,000

DATE: *6/05*
SOURCE: *California Energy Commission*

Figure 4: Brackish Water Desalination

Brackish Ground Water Desalination

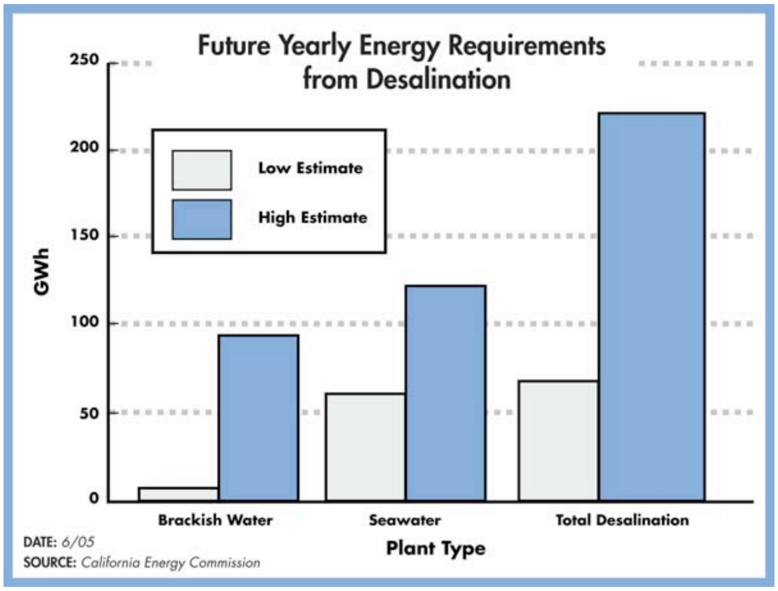
	In Operation[1]		In Design and Construction[2]		Planned or Projected[3]	
Data Source	Number of Plants	Capacity (Acre feet/Year)	Number of Plants	Capacity (Acre feet/Year)	Number of Plants	Capacity (Acre feet/Year)
Task Force (2003)	40	170,000			30-35	290,000
California Water Plan Update (DWR, 2005)	14	68,500	3	31,700	3	55,800

1. Number of Plants in Operation - Task Force assumes all desalination uses and DWR assumes municipal use of potable water
2. Design and Construction - Construction is underway or preparation of plans and specification has begun
3. Projected - Assumed new or expanded capacity of plants in operation or design and construction

DATE: *6/05*
SOURCE: *California Energy Commission*

DWR's recently released 2005 update to the California Water Plan is much more conservative about the future number of desalination plants than was the Task Force. The Water Plan Update predicts that water agencies will build an additional six brackish ground water desalting plants in the next 5-10 years, capable of producing nearly 87,500 acre-feet per year, and an additional seven seawater and estuarine desalination facilities that could produce about 187,150 acre feet per year, to meet future potable water supply needs (See Figure 5).

Figure 5: Future Yearly Energy Requirements from Desalination



Addressing the disparity between the Water Plan Update and the prediction made by the Task Force in 2003, DWR believes some of the differences can be attributed to eliminating double counting of plants, and narrowing the estimate to plants built to provide potable water. DWR believes the task force may have double-counted some plants and included plants being constructed to replenish and restore groundwater or rivers and streams in its prediction.

ACWA believes that DWR relies too heavily on water conservation to meet the future water demand, and asserts that the number of desalination plants required will be considerably higher than the number estimated by DWR. Other entities, such as the California Urban Water Conservation Council, believe conservation and efficiency hold considerably more cost-effective potential over desalination to increase drinking water supplies.

Clearly, there is not universal agreement on the number of desalination facilities that will be built in the near future. Desalination development will be dependent on facility economics, environmental conditions, and on cooperation of state and local planning agencies to permit facilities. Environmental considerations include developing seawater intakes that have acceptable impacts on the coastal zone, disposal of the brine concentrate discharge, land use and growth inducing impacts.

Unlike every other type of water facility, where staffing edges out energy use as the main expense, desalination's primary operating cost is for energy, with seawater desalination being considerably more energy intensive (9,780-16,500 kWh/million gallons) than brackish water desalination (3,900–9,750 kWh/million gallons. Most desalination plants operate continuously, so this electricity is used during all seasons, and all times of the day. Current plants are operating 90 percent of the time, with downtimes only for maintenance. (DWR, 2005)

Because of uncertainty in the future number of desalination plants and the variability of electricity costs, only a range of future electricity demand from desalination is estimated. Depending on the final number of plants and the technologies used, brackish water desalination will consume between 73 and 943 GWh of electricity per year, based on DWR's 2005 Water Plan Update figures. Seawater desalination is expected to use between 610 and 1,225 GWh per year. If all planned facilities are fully developed, overall electricity consumption could increase by 2,150 GWh annually.

IV. PROGRAMS AND METHODS FOR REDUCING PEAK AND OVERALL ENERGY USE IN THE WATER SECTOR

Fortunately, many effective options exist for addressing the energy problems likely to arise as a result of changes in the water sector in coming years. This section highlights some of the successful programs in use today, discusses some of the barriers to effective implementation of such programs, and offers potential actions to overcome those barriers.

Almost all water and energy conservation, efficiency and peak-load reduction programs have three common institutional or fundamental barriers to their complete success: inadequate funding, inflexibility, and lack of follow-up. The water agency personnel involved in the development of this staff paper, which totaled into the hundreds thanks to the participation of several key industry organizations, were in agreement that lack of long-term funding was the number one impediment to successful and lasting success in implementing water and energy efficiency and conservation programs. More than a few excellent programs died on the vine because promised long-term funding disappeared after a year or two, they stated, when state-backed funding programs dried up in the political heat of the budget process.

Number two on their hit parade was lack of flexibility in program design to accommodate their decision-making processes. According to dozens of water agency professionals, they have missed many opportunities because their municipal decision-making process cannot accommodate the tight deadlines for submittal of requests and follow-up documents during state or regional grant or loan application and award processes.

But perhaps the most daunting problem in ensuring that programs have their intended effects is addressing the “human factor” by following up on all programs over time. The human side of the equation is a factor in essentially every water conservation, efficiency or peak-load reduction program. For example, a family can install an on-demand water heater near the bathroom to save water and energy by not having to wait for the water to get hot, but then they all might start taking longer showers because they now essentially have an infinite supply of hot-water on hand. A farmer can install a fancy irrigation controller, but if it is too difficult to program, he will not use it; and if he was already doing a good job before the controller was installed, it will not provide any savings. Drip irrigation might save water over other forms of irrigation, but only if the farmer actively monitors and adjusts watering levels to provide only the exact amount needed, and even then he still might be using more electricity than he did before going to drip. And water agencies can install extra sensors and control equipment so they can shift more load from peak to on-peak, but if they have no incentive to do so, they likely will not place emphasis on reducing peak load to the maximum extent possible.

All of the example problems above can be summarized with the phrase "hardware is only as good as its management." Peter Canessa of the Center for Irrigation Technology presents the human behavior aspect from another angle when describing the energy-efficiency issue as a "non-point source problem." Fixing these types of problems generally involves changing the behavior of the players involved, including people specifying system hardware, people operating the hardware, and the people in charge of following up on program performance. Programmatic solutions to these problems must involve 1) raising awareness of the problem, 2) raising awareness of potential solutions, and 3) providing targeted resources for as long as necessary. (Canessa 2004)

Put another way, solving the energy problems presented by water system design and operation will require the energy and water sector to cooperatively:

1. innovate (Research, Development and Demonstration);

2. educate (establish measurement protocols, collect data, provide data–as databases, product labels, web tools–inform consumers and agencies) such as through a "clearinghouse of information";

3. motivate (pricing, incentives {rebates, grants, loans, feebates,tax credits, provide tools and turnkey solutions});

4. mandate (regulations); and,

5. operate (measurement and evaluation of field experience, feedback to steps 1-4).

Water agency professionals at the local level for decades have had one and only one objective: to maintain adequate water quality and pressure. Whatever energy use that was incurred in the process generally was passed straight through to the customer. The water world speaks a different language than the energy world, and their interactions have not always been successful. The assistance provided by the energy sector to the water sector can be improved considerably, and perhaps vice-versa.

Assistance to end users is also especially a challenge, since thousands, even hundreds of thousands, of people may be involved. For example, according to ITRC, the actual change in water use once a farmer switches to drip irrigation is almost as likely to increase as it is to decrease because so many human decisions are involved: the farmer has to know how much water was used before, and calculate through use of known evapo-transpiration rates and other data the ideal amount of water needed through the drip system, adjust the pump controller to ensure only that amount is delivered, and then follow-through to ensure the desired results are achieved. But many farmers do not have the time, resources or sufficient incentive to conduct such follow-up, which is why so many drip systems likely are overwatering. Conversely, many other farmers likely were underwatering their crops prior to installing drip systems, and then through improved management tend to increase their energy use as they learn to apply the proper amount. Another factor is the scale of effect at the individual level. Water savings per customer for a given program may be relatively modest, though they cumulatively provide great savings, meaning the customer may not have a great incentive to carry through. Put another way, it is hard to get a farmer to worry about $200 worth of water when he has a $100,000 lettuce crop in the field.

Another issue is economy of scale. Here, for example, large wholesalers such as Metropolitan Water District have a huge advantage in that they can enact conservation and efficiency programs on very large scales, working with their water agency customers. Individual water agencies, especially small to medium-sized agencies that do not buy their water from large wholesale agencies, have modest resources, and can only reach a relatively small customer base. Therefore, implementing water conservation, efficiency and peak-load reduction will likely have greater effects if conducted on the widest scale possible, and preferably be state-wide or at least regionally focused.

For these reasons above, staff's main conclusion coming out of this paper is that electricity use in the water sector must be addressed on a very wide scope, and the effort involved must be maintained for an extended period of time. With potential for roughly doubling the electricity demand in the water sector in the next 5-10 years, perhaps to the point of threatening electric system reliability on a local or regional level, nothing less than a comprehensive approach by both the energy and water sectors is likely to succeed in ensuring this potential load growth is adequately addressed through effective programs.

As part of that effort, staff intends to first establish a clearinghouse of information concerning actual energy use in all stages of the water sector, as well as on programs and management options for addressing energy use and cost.

The Energy Commission identified six areas where collaboration between water and energy agencies is critical: planning, development, coordination, issue resolution, implementation, and data sharing and analysis. Each of these areas is briefly discussed below:

Planning

This report clearly shows a need for careful planning to fully account for energy implications of water sector infrastructure development and operation, as well as to fully take advantage of opportunities to provide benefits in many areas, including potable water service, wastewater treatment and disposal, energy use, associated air emissions, and natural gas price relief. Further work in this area could build off the foundation established by the Pacific Institute, which has developed a spreadsheet program that water agencies can use to estimate the energy and air emissions (available at: http://www.pacinst.org/resources/water_to_air_models/).

Working with other agencies and organizations, the Energy Commission could develop a database of information concerning design of water systems, showing the energy benefits of oversizing conveyance and distribution systems, for example, or the peak-load benefits of increasing storage flexibility.[10] It could also develop spreadsheets that would assist water agencies in their decisions to develop their own generating facilities, compared to continuing to purchase electricity from service providers.

Joint planning of water conservation and efficiency programs will also provide benefits across many disciplines. For example, one program that was unheard of just 10 years ago is Metropolitan's commercial kitchen pre-rinse spray valve retrofit program. By simply replacing the spray valve used in commercial kitchens to rinse dishes and cookware before it goes through the dishwasher, an entire string of benefits occurred. The water agency saved on water treatment and pumping costs because the new valves use less than half the water of the older ones. Wastewater agencies saved the avoided wastewater treatment and disposal from the reduced use; and both natural gas and electric utilities saved because of the reduction of energy use at the water and wastewater treatment facility, and the reduced need for heating the rinse water at the kitchen. What appeared to be a modest water savings program has resulted in large societal benefits across many sectors.[11]

Development

To ensure adequate and reliable service, both the energy and water systems require maintenance and renovation. To accommodate the state's growing demand, new facilities and new technologies will be needed. By coordinating the development of infrastructure expansions and modifications, water and energy agencies can ensure that needs are met, systems are efficient and can be optimized.

Coordination

Careful coordination between water and energy utilities is critical to ensuring growth in water sector energy use is kept to a cost-effective minimum, and that sufficient generation is available to meet that growth. This effort would largely involve opening and sustaining channels of communication between water and energy agencies and companies.

[10] Significantly less energy is required to move the same amount of water through a larger pipe than through a pipe operating at maximum flow.
[11] In this case, "societal benefit" refers to total avoided cost benefit in the water, wastewater and energy utility industries, as discussed in Appendix D.

Issue Resolution
With the wide variation in water system design and operation, and the unique water quality and supply problems that are found in different areas of the state, it is necessary to establish a means to deal with the energy implications of individual water-related issues as they arise. For instance, the Energy Commission could provide information concerning energy use related to one of several options for meeting increased water treatment requirements, and provide technical assistance to water agencies seeking to reduce their present or future energy use.

Implementation
It is important to provide information concerning ways to effectively implement water conservation and efficiency programs such that they have maximum overall benefit to the state. This would include identifying methods to implement programs on the widest appropriate scale, taking advantage of existing relationships in the industry, such as between wholesale water agencies and their agency customers, as well as establishing a means to both share the costs of the program, and get credit for the resultant savings.

Data Sharing and Analysis
Critical to meeting future energy challenges in the water sector is the ability to quickly respond to emerging problems, and adjust response as necessary to ensure maximum overall societal benefit. This includes an on-going effort to seek out and analyze new data and information concerning energy use and production in the water sector, and share that analysis with energy and water sector professionals. Information is a two-way street, and staff will encourage all parties to take advantage of this process to share new information.

The seed for staff's effort in addressing these issues is planted in Appendix D, which analyzes several existing water conservation, efficiency and peak-load reduction programs, and attempts to calculate both the energy savings (or costs) and water savings of each item. The intention is to identify programs that provide the greatest overall benefit (in avoided costs for water and the associated energy use) per dollar spent on the program. This analysis will continue through the WER staff paper review process, and will be revised based on the input of the WER Working Group and all reviewers of this staff paper.

V. WATER USE IN THE PETROLEUM AND ELECTRIC POWER INDUSTRIES

Though not a focus of this staff paper, water use in the energy sector is the flip side of the water-energy relationship. This section briefly examines water use in the petroleum and electric power industries. This section is not meant to be exhaustive nor comprehensive, but rather the start of a longer process to assess overall water use in the industrial sector in DWR's coming 2010 Water Plan, as well as a preface to the Energy Commission's present and future research efforts on the topic.

A. Petroleum Industry

The petroleum industry in California is an intense water user, especially in the refinery sector. Water use is also extensive for two types of Enhanced Oil Recovery (EOR) operations used to pump crude from wells: the waterflood method, in which water is pumped into a crude reservoir to replace the crude pumped out, thus maintaining pressure in the field; and the steamflood method, in which steam is injected into subsurface crude to decrease its viscosity, making it easier to pump to the surface.

Steam flood EOR is needed in California because much of the state's crude is extremely viscous. Waterflood is used more in other areas of the country and the world where the crude is relatively less viscous and under high pressure, often enough to push the crude to the surface without pumping. Waterflood has the advantage that virtually any type of water can be used -- recycled, brackish, even seawater -- and existing systems often use municipal wastewater for makeup.

EOR steam is generally supplied by natural gas-fueled boilers or cogeneration power plants located in the oil fields, at quality levels of about 80 percent steam and 20 percent water vapor. The water content is often separated and returned to the boiler, or disposed of, generally in abandoned wells or a brackish aquifer. (CH2M HILL 2003) Most of the oil fields in Kern County include extensive pipeline and utility systems, and their source of water is generally treated "process water," which is the water that accompanies the crude as it comes to the surface. But some get their water from other sources, such as treated municipal effluent and brackish groundwater. Small crude development projects typically dispose of the produced water and use fresh water to make steam. Use of boilers is more common because they can tolerate higher total dissolved solids (TDS) content in the water supply, whereas cogeneration plants typically require much less TDS in the feedwater. This means that boiler feedwater requires considerably less treatment compared to cogen feedwater, an advantage in the oil fields where process water TDS levels can reach 10,000 mg/L. (CH2M HILL 2003)

Refineries use water primarily for two general applications: steam production, and cooling water. In simplistic terms, the entire refining process involves heating, distilling and use of various catalysts to break up (or “crack”) the crude into its various byproducts, such as naphtha (which, when blended with octanes, creates gasoline), kerosene/jet fuel, diesel oil and residual fuel oil. Often the heat that is applied in one part of a process must be removed later on, requiring both heating and cooling in the same process. Cooling and boiler feedwater makeup together typically account for 80-90 percent of the total water consumption in a refinery, with utility water and potable water making up the balance. Refinery wastewater primarily comes from steam or condensate used in direct contact with crude constituents in the process stream, cooling tower blowdown, or as cleaning or flushing water. Process wastewater typically accounts for about two-thirds of the wastewater and cooling tower blowdown about one-third. However, refineries located in areas with extremes of temperature or humidity have different rates. (CH2M HILL 2003)

A typical refinery uses an average 65-90 gallons of water per barrel of crude oil processed, and produces about 50-60 gallons of wastewater that generally must be treated prior to reuse or disposal; the difference is lost through evaporation. (CH2M HILL 2003) California’s refineries collectively can process about 2 million barrels of crude per day at maximum production rates, which translates to 130-180 million gallons of water per day (about 390-430 acre-feet per day, or up to 157,000 acre-feet per year), and 100-120 million gallons of wastewater produced per day using the above figures. However, these figures are based on industry averages. Actual water use in California’s refinery industry is the subject of a separate Energy Commission staff report, entitled the Petroleum Infrastructure Environmental Performance Report, which is also part of the 2005 IEPR process. (available at http://www.energy.ca.gov/2005_energypolicy/notices/2004-12-01_committee_wkshp.html)

B. Power Plant Use

Conventional Thermal Power Plants

Power plant water use is extensive and intense. Power plants collectively consume about 4 million acre-feet per year of freshwater in the country (EIA, 2000. Form 767. Steam-Electric Plant Operation and Design Report. Schedule V. Cooling System Information. Section A. Annual Operations.). Thermal power plants especially, including nuclear, coal-fired, gas-fired, and geothermal plants, can consume large amounts of water, most of which is used in the cooling process.

Depending on the type of cooling tower, the cooling process can account for up to 95 percent of total plant water use. Most commonly, these plants use closed-loop evaporative cooling towers, which require large quantities of water to make up for water lost to evaporation in the towers. (Maulbetsch 2002) Large 500- to 1,000-megawatt combined-cycle facilities with closed-loop cooling may use 3.5 to

5 million gallons per day. Water use by other plants with closed-loop systems compares with that figure in proportion to their generating capacities. (California Energy Commission 2001)

Recognizing the impacts of power plant water use, the Energy Commission in December 2003 adopted a policy in the 2003 Integrated Energy Policy Report whereby it will no longer approve use of fresh water to provide makeup for power plant cooling systems (i.e., favoring instead use of degraded or recycled water, or air-cooled systems), nor anything but use of zero-liquid discharge (ZLD) systems to handle any wastewater, unless such use is “environmentally undesirable or economically unsound.” (CEC 2003 IEPR, December 2003) Power plant applications approved since adopting these policies have all specified use of recycled water as their primary source of water. Staff estimates that if all of the power plants currently projected to be built in California in the next five years used recycled water for cooling, approximately 118,000 acre-feet per year of fresh water could be diverted to other uses. (http://www.energy.ca.gov/sitingcases/all_projects.html)

The Energy Commission currently has no official policy concerning power plant once-through cooling technology, in which water is passed just once through a heat exchanger and returned to the body from which it came, usually the ocean. Rather, the Energy Commission considers each case individually. As with refinery water use, the potential impacts of power plant seawater once-through cooling systems, including impacts on water resources, is the subject of a separate report (the Once-Through Cooling appendix to the Electricity Environmental Performance Report) that is part of the 2005 IEPR Process. Please see the document list under the “November 15, 2004, Committee Workshop on Electricity Environmental Performance Report” header at: http://www.energy.ca.gov/2005_energypolicy/documents/2004_index.html#111504.

Renewable and Distributed Energy Production

Many renewable energy production facilities use no water at all during operations, including wind power and solar photovoltaic systems. From a water use perspective, geothermal and biomass plants are essentially identical to natural gas-fueled plants in that they require significant quantities of water to provide cooling water makeup, and would use significantly less water if they employed dry cooling technology. Some geothermal steam fields require water injection to maintain adequate steam supply pressure, usually using recycled or degraded water rather than fresh water for this purpose.

Distributed energy systems – the process of installing and operating many smaller generating facilities instead of fewer, centralized large plants – essentially are air-cooled machines, needing little to no water for power operations. Existing microturbine cogeneration facilities use automotive-type radiators to provide cooling, but if sized properly, essentially all the heat produced by the generator is used in the thermal process, such as providing zone heating for buildings or heating large swimming pools, and no additional cooling is needed.

VI. STAFF FINDINGS AND POLICY OPTIONS

Research conducted in support of the Water-Energy Relationship Staff Paper revealed several significant data gaps. Key among those is the lack of information concerning the potentially rapid and large increase in electricity demand and use in various stages of the water cycle. Because of the lack of data in those areas, staff can only provide general statements concerning likely trends in electricity use; estimating actual increases or decreases would be an exercise in futility.

Present Research

Much of the needed research, development and demonstration concerning water and wastewater treatment energy use was identified in the publication "Water and Wastewater Industry Energy, Efficiency Research Roadmap" (Roadmap) jointly developed by the Energy Commission's PIER program, the American Waterworks Association Research Foundation (AwwaRF) and the Water-Energy Research Foundation. The Roadmap identified the following key issues:

- Rising electricity costs to meet stringent water quality requirements.
- Rising electricity costs to enhance water supplies.
- Improving reliability to mitigate problems of grid and restructuring.
- Lack of a system-level energy-water link perspective for increasing energy efficiency.
- Non-technical barriers to optimize energy use and to foster energy savings.

The Roadmap identified 44 research and development (R&D) projects to address energy efficiency at water and wastewater treatment plants. The Energy Commission and AwwaRF together have committed over $2 million to fund these projects, including five projects that will address various issues identified in this staff paper. One of these is a contract a contract with EMA, Inc. to analyze demand forecasting tools used by the electric industry and some of the few water utilities using demand forecasting to make recommendations on the best methods for the water industry.

Another project is with HDR Engineering, Inc. for the "Evaluation of the Dynamic Energy Consumption of Advanced Water and Wastewater Treatment Technologies." This project will:

1. Quantify the actual and theoretical energy consumption of selected water and wastewater advanced treatment unit operations.
2. Evaluate the factors that affect energy consumption.
3. Identify energy optimization opportunities while maintaining treatment performance.

Future Research Needs

Staff has identified additional research needs in the following topic areas:

- Comprehensive implementation of energy management in water system planning and operation.
- Groundwater pumping.
- Water treatment energy requirements.
- Recycled water treatment and pumping.
- Digester gas and other renewable power production.
- Water market transaction trends.
- Agriculture water use.
- Peak-load reduction in the water sector.
- Pumped-storage and conduit hydropower potential.
- Energy impacts of water conservation and efficiency.
- Desalination.

Comprehensive Implementation of Energy Management in Water System Planning and Operation

An important next step is to build upon the foundation established by this study to set up a comprehensive program to assist water agencies in integrating energy management in every stage of water system planning and operations, from source to end use to wastewater disposal. This effort should especially focus on bringing an energy perspective to all stages of water use by watershed.

This comprehensive process should start by first developing a clearinghouse of energy-related information available to water professionals and others concerned about water use in California. Following that should be development of a pilot program, working with the Department of Water Resources, Association of California Water Agencies, California Association of Sanitation Agencies, the American Waterworks Association Research Foundation, Metropolitan Water District, and others, to help individual water agencies fully integrate energy planning and management into their activities. This effort should include direct and active technical assistance and also should involve identifying sources of long-term funding, as long-term funding was identified as the most critical factor in engaging support from within the water industry. The pilot program would provide information and assistance related to water and energy conservation and efficiency, peak-load reduction, and water system generation and also would set up a process to identify further research needs.

Depending on the results of the pilot, successful programs could be ramped up to provide assistance to water agencies state-wide. The results of the Water-Energy Relationship Staff Paper show that changes in the water sector could have very real, very dramatic, and very quick impact on electricity use patterns, perhaps to the point of threatening the reliability of the system. Anything less than a comprehensive approach in addressing these pressing issues facing both the water and energy sectors is not likely to succeed.

Groundwater Pumping

Because use of groundwater is largely unregulated in California, little data exists on its use, making estimations of associated electricity use very difficult. The Irrigation Training and Research Center (ITRC) study on agricultural energy requirements perhaps goes farther than any other, and bases much of its information on real-world geographical information system (GIS) data, but it must necessarily make many assumptions concerning average pump lift (groundwater levels), distribution uniformity, surface water availability (timing factor), irrigation type, average drawdown, discharge pressure,and so forth. It uses the real-world results of the pump efficiency tests conducted for the Agricultural Peak Load Reduction Program by the Center for Irrigation Technology, but those data did not include static or pumping water levels and primarily covered only wells in PG&E's territory.

The ITRC study also is the result of at least two levels of computer modeling: that by Department of Water Resources to estimate groundwater levels in Northern California and ITRC's own crop water model, which produced the energy use estimates in its groundbreaking study. Much of ITRC's results are based on what can only be described as rough calculated estimates by DWR for Central and Southern California groundwater volumes, which is especially critical in the Kings and Kern River Basins, where more than 50 percent of the energy used for agriculture-related groundwater pumping occurs. (A detailed discussion of ITRC's model can be found in their report No. 02-001, available on their website at www.itrc.org.)

Though ITRC has certainly provided useful information on agricultural irrigation electricity use and has helped spark the growing interest in the study of the water-energy nexus, little can be said about groundwater use at small farms and other residences dependent on groundwater.

The WER Staff Paper process presents an opportunity for the Energy Commission to work with the Department of Water Resources, the California Department of Food and Agriculture, the Irrigation Training and Research Center, the Center for Irrigation Technology, the National Laboratories, and other entities to develop methods to study groundwater-related electricity use. Research in this area should be based on real-world data to the maximum extent possible. Ideally, a well formulated groundwater monitoring program around the state would be the best alternative for such a study, tracking actual groundwater levels, pump production and electricity use,and other data over many years. This could build on existing groundwater monitoring programs, and could perhaps gain emphasis and funding when consideration of electric system reliability is included with water supply and use concerns.

Water Treatment Energy Requirements

Water agencies in the state are currently waiting to see the effects of several pending rules affecting treatment requirements that are set for final release next year. The energy effect of these rules is largely unknown, mostly because water agencies at present do not know what standards they must meet, or how they would meet them.

The Energy Commission could work with California Department of Health Services (CDHS), the State and Regional Water Quality Control Boards, other state agencies, the Association of California Water Agencies, American Waterworks Association and others to develop methods for quickly assessing the energy implications of pending rules. The Energy Commission could also consider actions that would encourage CDHS and other water quality regulating agencies to include analysis of potential increases in energy demand and cost in their rulemaking processes, especially since energy production, consumption and related emissions have health implications as well.

Recycled Water Treatment and Pumping

Available information indicates that electricity use at wastewater treatment facilities producing recycled water is as much as twice as high as those using only secondary treatment; but as municipalities find more applications for their recycled water, the pumping energy requirements associated with that use could dwarf the treatment-related electricity use.

Tracking this energy use could be accomplished by working with the state and regional water quality control boards, the California Association of Sanitation Agencies, Association of California Water Agencies, the American Waterworks Association Research Foundation, the Water Reuse Foundation, and other entities to develop methods to study current and future electricity use related to development of recycled water facilities and systems. This would include, for example, comparison of the energy used in the recycled water system to that used by other water supplies to determine the net impact on energy use in a given system. The California Association of Sanitation Agencies, Association of California Water Agencies and American Waterworks Association could also act as conduits to supply information concerning tertiary treatment development, and related electricity demand growth, from their members.

Digester Gas and Other Renewable Power Production

Staff’s study of potential digester gas power production at wastewater facilities shows that current potential is modest, at best. However, a cursory study of the research in this area reveals that this sector could perhaps have a considerably greater potential to generate power than current estimates, especially if their fuel feedstock is combined with other biosolids, such as dairy animal waste and food refuse. Many agencies, universities, associations, and individual companies are conducting research in this area, and recent developments show some promise in coming years to more fully utilize this resource, including the possible development of a sludge-derived solid fuel that could be burned in power plants. The California Association of Sanitation Agencies (CASA) in 2003 launched a biosolids research, development and demonstration (RD&D) effort to sponsor or support university research, share information, and foster cooperation with government agencies and others in its mission to promote environmentally sound recycling of biosolids (www.casaweb.org).

The Energy Commission could work with CASA and other agencies and organizations involved in biosolids research to gather information on the state of digester gas production and the potential to increase that production. Based on the results of this information gathering process, there may be opportunities for the Energy Commission to help foster further RD&D in this area.

The water and wastewater treatment sectors also offer significant potential for development of solar power facilities on their properties. Several agencies are already installing such systems, and many more have expressed interest in doing so. To take advantage of this interest, the Energy Commission could work with the Association of California Water Agencies, the California Association of Sanitation Agencies, the California Public Utilities Commission, the California Independent System Operator, the state's electric utilities and others to explore the issues associated with development of solar generation at water and wastewater facilities.

Water Market Transaction Trends

When considering that many water market transactions are increasing the energy "cost" of water conveyance from essentially zero to as much as 9,000 kWh/million gallons, while others actually reduce pumping energy use, the changes in conveyance patterns is another area that deserves close consideration. The Energy Commission could work with the Association of California Water Agencies, the Department of Water Resources/State Water Project, Bureau of Reclamation, Metropolitan Water District, Los Angeles Department of Water and Power, Irrigation Training and Research Center, and others involved in contracting for or providing conveyance services to first determine the likely extent of such transactions, and make a rough estimate of the magnitude of change in electricity use patterns. If warranted, staff would recommend further study of methods to track such transactions and determine and prepare for their energy impact.

Agriculture Water Use

The Energy Commission could work with California Department of Food and Agriculture, U.S. Department of Agriculture, Irrigation Training and Research Center, Center for Irrigation Technology, UC Davis Cooperative Extension and others to develop methods for actively tracking energy use trends associated with changes in crop planting and harvesting patterns. Similarly, this effort could be extended to track energy trends associated with irrigation technology use, especially associated with installation of pressurized irrigation systems (drip and spray) on fields now irrigated by gravity and the conversion of diesel-engine pumps to motor-driven pumps.

To address the potential increase in energy use in the agricultural sector, staff fully supports the research goals listed in PIER's Technology Roadmap, as detailed in the publication, *Water Use Efficiency in California Agriculture* (California Energy Commission, PIER Agricultural Energy Efficiency Program 2003).

Peak-Load Reduction in the Water Sector

One of the more positive findings of this study was the apparent high peak-load reduction capability in the water sector. According to the Association of California Water Agencies (ACWA) , its members could quickly and relatively cheaply install sensors and other equipment that would give them considerably more flexibility in operating their present systems. This flexibility would allow them to maintain minimal pumping loads during peak periods, either by delaying such use into the evening hours or at least by cycling such loads sequentially to minimize peak use. ACWA members expressed interest in working with the Energy Commission to achieve meaningful additional peak load reduction as early as this summer. The Energy Commission could immediately begin a cooperative work effort with ACWA, the California Association of Sanitation Agencies, the California Public Utilities Commission, the utilities and others to explore and take advantage of this opportunity through RD&D projects, and promote funding of promising programs.

Pumped-Storage and Conduit Hydropower Potential

Though staff's cursory review of existing pumped-storage operations reveals that most are likely operated at near optimum levels, some perhaps could be enhanced to allow more flexibility in their operations. To help maximize available resources to meet peak needs, the Energy Commission could build upon its policy to promote a planning effort concerning use of pumped-storage generation by taking advantage of the dedicated group of professionals who have generously devoted their time to helping develop this study. The Water-Energy Relationship Working Group established for this effort has proved an invaluable source of information, as well as an excellent peer review group. The Energy Commission and other agencies could use the resources of the Working Group to further explore methods to maximize the value in existing pumped-storage systems, as well as explore potential new project development, and in general participate in all of the research efforts above.

The WER Staff Paper identified only modest potential for further development of conduit hydropower facilities. However, these facilities offer a cost-effective means of developing new renewable power production, with significantly reduced environmental impact compared to other hydropower facilities. The Energy Commission could work with the California Association of Water Agencies, the California Public Utilities Commission, the Federal Energy Regulatory

Commission, the utilities, the National Laboratories and others to fully explore the potential for developing such facilities, including identifying barriers to such development and means to overcome them.

Energy Impacts of Water Conservation and Efficiency

Staff looks forward to the results of the current PIER-funded effort by UC Santa Barbara and the Pacific Institute to quantify energy use in every stage of the water cycle, including applications on the customer side of the meter. This study should provide extremely valuable information concerning exact energy use in each sector, which will help focus future conservation and efficiency programs in areas where they will do the most good. Critical in that effort will be to determine to the extent practical the energy effects of present and future water conservation and efficiency efforts, and attempt to influence implementation of those programs that show the greatest cost effectiveness in reducing both water and energy use.

The Energy Commission could work with the Department of Water Resources, California Urban Water Conservation Council, Electric Power Research Institute, the utilities, Association of California Water Agencies, California Association of Sanitation Agencies, Metropolitan Water District, other individual water and wastewater agencies, the National Laboratories and others involved in planning, funding or implementing water conservation and efficiency measures, to develop methods for identifying and promoting those efforts that provide the maximum societal value. This effort should also include effort to identify and break down barriers to effective long-term implementation of these programs.

Desalination

Though the WER Staff Paper identified only fairly modest impacts on the electric system from known planned desalination plant development, the number of planned facilities could increase quickly if one or both of two things occur: an extended drought or other scenario that significantly curtails surface water deliveries and/or a significant decrease in the cost of operating such facilities. Assessing the magnitude of desalination development would require periodic updating of existing proposals and analysis of the potential energy effects of those proposals. This could be accomplished through a working group or task force process, such as reviving the Water Desalination Task Force established by the Department of Water Resources.

The Task Force, comprised of representatives of 27 organizations, participated in development of a report to the Legislature on the potential opportunities and impediments to using seawater and brackish water desalination, and in examining what role the state should play in furthering the uses of desalination technology. In 2003, DWR published the report titled *Water Desalination: Findings and Recommendations*. DWR concluded that significant opportunities exist for desalination to provide potable water to meet California's water demand, to relieve drought conditions, to replace and restore groundwater, and to provide a source of water for river and stream ecosystem restoration.

Another past task force consisting of Energy Commission, DWR, and other representatives was established in 2003 to guide funding of water projects under Proposition 50, the Water Quality, Supply and Safe Drinking Water Projects, Coastal Wetlands Purchase and Protection Act. Proposition 50 authorized the sale of $3.4 billion in general obligation bonds for a variety of water projects, including coastal protection, the CALFED Bay-Delta Program, integrated regional water management, safe drinking water, and water quality. The Task Force assisted DWR in recommending that the available $25 million under the current desalination grant cycle be used to fund 25 projects.

Continuing these partnerships with DWR and other stakeholders could provide an effective means to accurately estimate the future supply of desalinated water, refine estimates of the energy impacts of the various desalination technologies, and assist in developing more energy efficient desalination technologies. Part of that effort could include coordination of PIER research with the goal of reducing the energy requirements of desalination facilities.

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GLOSSARY

acre-foot (AF) - a quantity or volume of water covering one acre to a depth of one foot; equal to 43,560 cubic feet or 325,851 gallons.

active storage capacity - the total usable reservoir capacity available for seasonal or cyclic water storage. It is gross reservoir capacity minus inactive storage capacity.

adjudication –The act of judging or deciding by law. In the context of an adjudicated groundwater basin, landowners or other parties have turned to the courts to settle disputes over how much groundwater can be extracted by each party to the decision.

afterbay - a reservoir that regulates fluctuating discharges from a hydroelectric power plant or a pumping plant.

alluvium - a stratified bed of sand, gravel, silt, and clay deposited by flowing water.

aquifer - a geologic formation that stores and transmits water and yields significant quantities of water to wells and springs.

artificial recharge – The addition of water to a groundwater reservoir by human activity, such as putting surface water into dug or constructed spreading basins or injecting water through wells.

average annual runoff - the average value of annual runoff amounts for a specified area calculated for a selected period of record that represents average hydrologic conditions.

brackish water - water containing dissolved minerals in amounts that exceed normally acceptable standards for municipal, domestic, and irrigation uses. Considerably less saline than sea water.

conjunctive use – The coordinated and planned management of both surface and groundwater resources in order to maximize the efficient use of the resource; that is, the planned and managed operation of a groundwater basin and a surface water storage system combined through a coordinated conveyance infrastructure. Water is stored in the groundwater basin for later and planned use by intentionally recharging the basin during years of above-average surface water supply.

contaminant – Any substance or property preventing the use or reducing the usability of the water for ordinary purposes such as drinking, preparing food, bathing washing, recreation, and cooling. Any solute or cause of change in physical properties that renders water unfit for a given use. (Generally considered synonymous with pollutant.)

conveyance – Provides for the movement of water and includes the use of natural and constructed facilities including open channels, pipelines, diversions, fish screens distribution systems and pumplifts.

desalination – Water treatment process for the removal of salt from water for beneficial use. Source water can be brackish (low salinity) or seawater.

drainage basin - the area of land from which water drains into a river; for example, the Sacramento River Basin, in which all land area drains into the Sacramento River. Also called, "catchment area," "watershed," or "river basin."

drip irrigation – A method of microirrigation wherein water is applied to the soil surface as drops or small streams through emitters. Discharge rates are generally less than 8 L/h (2 gal/h) for a single outlet emitters and 12 L/h (3 gal/h) per meter for line-source emitters.

drought – The magnitude and probability of economic, social or environmental consequences that would occur as a result of a sustained drought under a given study plan. Measures the "drought tolerance" of study plans.

energy consumption – The energy consumption required to facilitate water management-related actions such as desalting, pump-storage, groundwater extraction, conveyance or treatment. This criterion pertains to the economic feasibility of a proposed action in terms of O&M costs.

energy costs – Refers to the cost of energy use related to producing, conveying and applying water. It also refers to the cost of energy use for processes and inputs not directly related to water, but which can affect the demand for water (e.g., the cost of nitrogen fertilizer, tractor manufacturing, etc.).

energy production – Both instantaneous capacity (megawatt) and energy produced (kilowatt hours).

effluent - waste water or other liquid, partially or completely treated or in its natural state, flowing from a treatment plant.

estuary - the lower course of a river entering the sea influenced by tidal action where the tide meets the river current.

evapotranspiration (ET) - the quantity of water transpired (given off), retained in plant tissues, and evaporated from plant tissues and surrounding soil surfaces. Quantitatively, it is usually expressed in terms of depth of water per unit area during a specified period of time.

forebay - a reservoir or pond situated at the intake of a pumping plant or power plant to stabilize water levels; also a storage basin for regulating water for percolation into ground water basins.

gigawatt (GW) -- One thousand megawatts (1,000 MW) or, one million kilowatts (1,000,000 kW) or one billion watts (1,000,000,000 watts) of electricity. One gigawatt is enough to supply the electric demand of about one million average California homes.

gigawatt-hour (GWh) -- One million kilowatt-hours of electric power. California's electric utilities generated a total of about 250,000 gigawatt-hours in 2001.

gross reservoir capacity - the total storage capacity available in a reservoir for all purposes, from the streambed to the normal maximum operating level. Includes dead (or inactive) storage, but excludes surcharge (water temporarily stored above the elevation of the top of the spillway).

groundwater - water that occurs beneath the land surface and completely fills all pore spaces of the alluvium, soil or rock formation in which it is situated. It excludes soil moisture, which refers to water held by capillary action in the upper unsaturated zones of soil or rock.

ground water basin - a ground water reservoir, defined by an overlying land surface and the underlying aquifers that contain water stored in the reservoir.

ground water overdraft - the condition of a ground water basin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin over a period of years during which water supply conditions approximate average.

ground water recharge - increases in ground water storage by natural conditions or by human activity.

ground water table - the upper surface of the zone of saturation, except where the surface is formed by an impermeable body.

hydraulic barrier - a barrier developed in the estuary by release of fresh water from upstream reservoirs to prevent intrusion of sea water into the body of fresh water.

hydrologic balance - an accounting of all water inflow to, water outflow from, and changes in water storage within a hydrologic unit over a specified period of time.

hydrologic basin - the complete drainage area upstream from a given point on a stream.

hydrologic region - a study area, consisting of one or more planning subareas.

infiltration – The flow of water downward from the land surface into and through the upper soil layers.

irrigation efficiency (IE) - The efficiency of water application and use, calculated by dividing a portion of applied water that is beneficially used by the total applied water, expressed as a percentage The two main beneficial uses are crop water use (evapotranspiration, etc.) and leaching to maintain a salt balance.

kilovolt (kV) - One-thousand volts (1,000). Distribution lines in residential areas usually are 12 kv (12,000 volts).

kilowatt (kW) - One thousand (1,000) watts. A unit of measure of the amount of electricity needed to operate given equipment. On a hot summer afternoon a typical home, with central air conditioning and other equipment in use, might have a demand of 4 kW each hour.

kilowatt-hour (kWh) - The most commonly-used unit of measure telling the amount of electricity consumed over time. It means one kilowatt of electricity supplied for one hour. In 1989, a typical California household consumes 534 kWh in an average month.

land subsidence – The lowering of the natural land surface due to groundwater (or oil and gas) extraction.

maximum contaminant level (MCL) – The highest drinking water contaminant concentration allowed under federal and State Safe Drinking Water Act regulations.

megawatt (MW) -- One thousand kilowatts (1,000 kW) or one million (1,000,000) watts. One megawatt is enough energy to power 1,000 average California homes

methane (CH_4) -- the simplest of hydrocarbons and the principal constituent of natural gas. Pure methane has a heating value of 1,1012 Btu per standard cubic foot.

methanol (also known as Methyl Alcohol, Wood Alcohol, CH_3OH) -- a liquid formed by catalytically combining carbon monoxide (CO) with hydrogen (H_2) in a

1:2 ratio, under high temperature and pressure. Commercially it is typically made by steam reforming natural gas. Also formed in the destructive distillation of wood

microirrigation – The frequent application of small quantities of water as drops, tiny streams, or miniature spray through emitters or applicators placed along a water delivery line. Microirrigation encompasses a number of methods or concepts such as bubbler, drip, trickle, mist, or spray.

minimum pool - the reservoir or lake level at which water can no longer flow into any conveyance system connected to it.

natural recharge – Natural replenishment of an aquifer generally from snowmelt and runoff; through seepage from the surface.

percolation – Process in which water moves through a porous material, usually surface water migrating through soil toward a groundwater aquifer.

photovoltaic cell - A semiconductor that converts light directly into electricity

public water system – A system for the provision of water for human consumption through pipes or other constructed conveyances that has 15 or more service connections or regularly serves at least 25 individuals daily at least 60 days out of the year.

recharge – Water added to an aquifer or the process of adding water to an aquifer. Groundwater recharge occurs either naturally as the net gain from precipitation or artificially as the result of human influence.

recycled water – The process of treating municipal, industrial, and agricultural wastewater to produce water that can be productively reused.

riparian right – A right to use surface water, such right derived from the fact that the land in question abuts the banks of streams.

runoff – The volume of surface flow from an area.

salinity – Generally, the concentration of mineral salts dissolved in water. Salinity may be expressed in terms of a concentration or as electrical conductivity. When describing salinity influenced by seawater, salinity often refers to the concentration of chlorides in the water.

seawater intrusion barrier – A system designed to retard, cease or repel the advancement of seawater intrusion into potable groundwater supplies along coastal portions of California. The system may be a series of specifically placed injection wells where water is injected to form a hydraulic barrier.

surface supply – Water supply obtained from streams, lakes, and reservoirs.

surplus water – Water that is not being used directly or indirectly to benefit the environmental, agricultural or urban use sectors.

transpiration – An essential physiological process in which plant tissues give off water vapor to the atmosphere.

Urban Water Management Planning Act – Sections 10610 through 10657 of the California Water Code. The Act requires urban water suppliers to prepare urban water management plans which describe and evaluate sources of water supplies, efficient uses of water, demand management measures, implementation strategies and schedules, and other relevant information and programs within their water service areas. Urban water suppliers (CWC Section 10617) are either publicly or privately owned and provide water for municipal purposes, either directly or indirectly, to more than 3,000 customers or supply more than 3,000 acre-feet of water annually

volt - a unit of electromotive force. It is the amount of force required to drive a steady current of one ampere through a resistance of one ohm. Electrical systems of most homes and office have 120 volts.

water balance – An analysis of the total developed/dedicated supplies, uses, and operational characteristics for a region.

water quality – Description of the chemical, physical, and biological characteristics of water, usually in regard to its suitability for a particular purpose or use.

watershed – The land area from which water drains into a stream, river, or reservoir.

APPENDIX A: DETAILED DESCRIPTION OF MAJOR WATER STORAGE AND CONVEYANCE STRUCTURES IN CALIFORNIA

Central Valley Project

Located in the northern part of the state, the Central Valley Project (CVP) is a federal flood control, power generation and water conveyance project administered and managed by the Bureau of Reclamation. The project's 20 dams and reservoirs, 39 pumping plants, 11 powerplants, and 500 miles of major canals manage nearly 9 million acre-feet of water annually, delivering water to customers from Redding to Bakersfield. It includes storage reservoirs on the Trinity, Sacramento, American, Stanislaus, and San Joaquin Rivers, and four major canals: the Tehama-Colusa Canal, the Contra Costa Canal, the Delta-Mendota Canal, and the Friant-Kern Canal.

Of the 9 million acre-feet that travel through CVP facilities, about 5 million acre-feet of water is delivered to farms in Northern California, enough to irrigate about 3 million acres of land, or approximately one-third of the agricultural land in California. About 600,000 acre-feet is delivered to municipal and industrial users, enough to supply about 1 million households for one year. The balance of the water flows is devoted to efforts to improve wildlife habitat in streams and on wildlife refuges in Northern California (in general, water flows for this purpose are called "environmental flows"). (USBOR Dataweb website)

With the exception of a single reservoir on the San Joaquin River, all other CVP reservoirs eventually drain into the Sacramento-SanJoaquin River Delta, where contracted amounts can be lifted through the Tracy and Contra Costa Pumping Plants into the Contra Costa and Delta-Mendota Canals. The relatively small Contra Costa Canal serves water agencies in the North San Francisco Bay area, while the 115-mile Delta-Mendota Canal, the largest in the system in terms of flow, travels south along the west side of the San Joaquin Valley, delivering water along the way to irrigation users, as well as into storage or into the California Aqueduct at the San Luis Reservoir (see below), and, at its terminus, into the San Joaquin River near Mendota.

The smaller Friant-Kern Canal carries water more than 150 miles from the lone San Joaquin River reservoir to the Kern River, four miles west of Bakersfield, delivering irrigation supplies to users in Fresno, Tulare, and Kern Counties. The 35.9-mile-long Madera Canal carries water north from Millerton Lake to irrigate lands in Madera County. Water withdrawn from the San Joaquin River into these canals can be replaced further downstream by Delta water from the Delta-Mendota Canal.

On the energy side, the CVP is a net energy producer. The CVP's hydroelectric facilities produce about 5,600 gigawatt-hours (GWh) of electricity annually, which is considerably higher than the 1,300-1,400 GWh used by its pumping facilities. Total power production capacity is about 2,100 MW, while total pumping demand is about 600 MW. All Central Valley Project pumping plants are served by project generation facilities. (Mortimer 2005)

State Water Project

The State Water Project (SWP) is a complex network of pumping and power plants, 21 major reservoirs and lakes, and more than 662 miles of canals, tunnels, and pipelines designed to move water from the Feather River basin in Northern California to users in the Central Valley and Southern California. It is the nation's largest state-built water and power development and conveyance system, supplying water to 29 water agencies.

Rain and melting snow run off into Lake Oroville, the official headwaters of the SWP and part of a complex that includes three power plants totaling 773 MW in generating capacity. When it is needed, water is released from Lake Oroville into the Feather River, where it flows downriver, converges with the Sacramento River, and then into the Sacramento-San Joaquin Delta. Some of the water is pumped by the Barker Slough Pumping Plant into the North Bay Aqueduct, which serves Solano County and, through the Cordelia Pumping Plant, portions of Napa County and the cities of Vallejo and Benicia.

The remaining water travels further south in the Delta and into the Clifton Court Forebay, where the Banks Pumping Plant lifts it into the 444-mile-long California Aqueduct. Its first way station is the Bethany Reservoir, where some of it is pumped by the South Bay Pumping Plant into the South Bay Aqueduct for deliveries to Alameda and Santa Clara counties. The remainder flows south by gravity into the San Luis Joint-Use Complex, consisting of the O'Neill Forebay, Sisk Dam and San Luis Reservoir, the Gianelli Pumping-Generating Plant, Dos Amigos Pumping Plant, and the San Luis Canal. This Joint-Use section of the California Aqueduct marks the point where the Central Valley Project and State Water Project merge.

After leaving the Joint-Use Complex, water travels south through the central San Joaquin Valley in the San Luis Canal to Kettleman City, where it connects with the Coastal Branch Aqueduct, serving San Luis Obispo and Santa Barbara counties through five pumping plants; this interconnect also marks the end of the joint-use complex, and the restart of the state-owned California Aqueduct. Water in this part of the aqueduct is pumped up over the Tehachapi Mountains by four pumping plants -- Buena Vista, Teerink, Chrisman, and Edmonston. The latter is the State Water Project's largest, consisting of 14 motor-pump units, each rated at 80,000 horsepower, standing 65 feet tall and weighing more than 400 tons, which lift water nearly 2,000 feet up and over the crest of the Tehachapis through

10 miles of tunnels. Each motor draws about 120 MW at full power, for a total potential load of 1,680 MW if all 14 units run at full power.

As the water reaches the bottom of the Tehachapis, it splits into two branches: the West Branch and the East Branch (the mainstem). Water in the West Branch is pumped by the Oso Pumping Plant into Quail Lake, where it enters a pipeline leading into the Warne Powerplant to generate power. This water discharges into Pyramid Lake, travels through Angeles Tunnel, and into Castaic Powerplant (the latter two are joint developments by the Department of Water Resources and the Los Angeles Department of Water and Power). At the end of the West Branch is Castaic Lake and Castaic Lagoon, a popular Southern California recreation spot.

Water flowing down the East Branch generates power at the Alamo Powerplant, then is pumped 540 feet uphill by the Pearblossom Pumping Plant. From there, it flows downhill through an open aqueduct to four underground pipelines that carry it into the Mojave Siphon Powerplant, which discharges the water into Lake Silverwood. When water is needed, it is discharged from the lake into the Devil Canyon Powerplant and its two afterbays. The 28-mile-long Santa Ana Pipeline then takes it underground to Lake Perris, the southernmost SWP facility and one of Southern California's most popular recreation spots.

The SWP pumping plants collectively consume about 8,000 GWh of electric energy each year, and the generating plants produce an average of about 6,000 GWh per year, for a net energy use of about 2,000 GWh. Its nine hydroelectric plants (Hyatt, Thermalito, Gianelli, Warne, Castaic, Alamo, Thermalito Diversion Dam, Mojave, and Devil Canyon) have a total capacity of about 1,475 MW. However, energy use and production is highly variable, depending on hydrologic and storage conditions. For example, over the period 1990-2001, net energy use varied from a low of 3.4 GWh in 1998 (a very wet year with high hydroelectric production), to a high of 8.2 GWh in 1990, in the middle of the 1987-1992 drought. (CEC DAO 2005)

Colorado River Aqueduct

Constructed largely to meet Southern California's water needs, the Colorado River Aqueduct flows from Lake Havasu in Western Arizona more than 240 miles to Los Angeles County. It includes 92 miles of tunnels, 63 miles of concrete canals, 55 miles of concrete conduits, and 144 siphons, totaling 29 miles. The project also includes five large pumping plants that lift the water a total of 1,617 feet, collectively using about 2.24 GWh of electricity per year. Though technically a net energy user, the aqueduct was constructed jointly with several federal hydroelectric projects on the Colorado River, including Hoover, Parker and Davis Dams, totaling 2,450 MW in generating capacity and producing 5.646 GWh of electricity in 2004.

The Colorado River Aqueduct was funded by and is still administered by the Metropolitan Water District (Metropolitan), which was created by special legislation in 1928 solely for the purpose of constructing the aqueduct. Metropolitan is now a wholesale water agency that serves 14 cities, 12 municipal water districts, and a county water authority in the greater Los Angeles area. More than 130 municipalities and many unincorporated areas get their water through the Colorado River Aqueduct.

Starting at Parker Dam, the aqueduct crosses the southern Mojave Desert, skirting several small mountain ranges and the southern edge of Joshua Tree National Park. It then enters the Coachella Valley north of the Salton Sea and turns northwest along the Little San Bernardino Mountains, crossing the San Jacinto Mountains west of Palm Springs and terminating at Lake Mathews in western Riverside County. About 20 miles from its terminus, the first San Diego Aqueduct splits off to send water 70 miles south by gravity to San Diego County; a second San Diego Aqueduct branches off the Casa Loma Canal, which branches off the CRA just downstream of its interconnect with the first San Diego Aqueduct. The second aqueduct sends water 94 miles south by gravity to Otay Reservoir. (Source: Metropolitan Water District Website, http://www.mwdh2o.com/mwdh2o/pages/yourwater/supply/colorado/colorado04.html, and Colorado River Water Users website, http://www.crwua.org/ca/crwua_ca.htm)

Los Angeles Aqueduct

The historical Los Angeles Aqueduct is capable of carrying 485 cubic feet of water per second more than 220 miles from the Owens Valley on the East Side of the Sierra to the City of Los Angeles. A second aqueduct added in 1970, at a cost of $89 million, is capable of transporting 290 cubic feet per second more than 137 miles from the Haiwee Reservoir in Southern Inyo County to Los Angeles. The Los Angeles Aqueduct neither consumes nor produces electric power, using only gravity to move water across the state.

Mokelumne Aqueduct

The East Bay Municipal Utility District’s Mokelumne Aqueduct carries water from the Pardee Reservoir on the Mokelumne River in Calaveras County 90 miles across the San Joaquin Valley through Stockton to East Bay reservoirs. EBMUD completed the first phase of the aqueduct during a supply emergency in 1929, when it had just a 21-day supply of brackish water left in local reservoirs. It has since added two more aqueducts to parallel the first, delivering a total of 82 billion gallons to its retail customers last year (2004 Annual Report), which collectively provided service to 1.3 million people. EBMUD’s system is gravity fed to the Bay Area, requiring no pumping; and with its 23.6 MW powerhouse at Pardee Dam, EBMUD’s conveyance system is a net energy producer.

Hetch Hetchy Regional Water System

The Hetch Hetchy System consists of more than 280 miles of pipelines, 60 miles of tunnels, 11 reservoirs, five pump stations and two water treatment plants. It provides water to 2.4 million people in San Francisco, Santa Clara, Alameda and

San Mateo counties. About 85 percent of that water comes from Sierra Nevada snowmelt stored in the Hetch Hetchy reservoir, on the Tuolumne River in Yosemite National Park. Gravity moves the Hetch Hetchy water 160 miles to the San Francisco Bay Area through very large pipes (penstocks) buried beneath the Valley floor. The remaining 15 percent of the System's water comes from local rain runoff captured in reservoirs in San Mateo and Alameda Counties. The entire system delivers an average of approximately 260 million gallons of water per day to its customers. Pumping is only needed after the water reaches the Bay Area and is stored in local reservoirs.

The Hetch Hetchy system also includes three major powerhouses that produce power from water released from three reservoirs: Hetch Hetchy, Lake Eleanor and Lake Lloyd (also called Cherry Lake). Lake Eleanor Water drains into Cherry Lake, which then drains through 165 MW Holm powerhouse as it flows into the Tuolumne River via Cherry Creek. Hetch Hetchy water flows through the 117.6 MW Kirkwood and 100 MW Mocassin Powerhouses. The power system delivers an average of 1.7 GWh of electricity annually to the City and County of San Francisco, the Modesto and Turlock Irrigation Districts and tenants at the San Francisco International Airport.

All American Canal System

Completed in 1940, the All-American Canal System carries water from the Colorado River westward along the U.S./Mexico border to irrigate fields in the Imperial Valley in the southeastern corner of California. It is partially administered by the Bureau of Reclamation, and partially by the Imperial Irrigation District (IID). The All-American system consists of the Imperial Diversion Dam and Desilting Works, the 80-mile All-American Canal, and the 123-mile Coachella Canal. The system irrigates about 530,000 acres in the Imperial Valley and 78,530 acres in the Coachella Valley; it also supplies water to the federal Yuma Project, which serves farms in Arizona and California near the City of Yuma.

The System's energy facilities include both generating stations and pumping plants. IID operates nine powerplants along the canal, totaling about 57 MW in generating capacity. Included among those is the 7 MW Pilot Know plant, which has the capability of producing power from water in the canal, but returns it to the Colorado River near the Mexican Border to meet international treaty requirements. IID is by far the largest user of canal water, feeding into a labyrinth of canals and drains totaling more than 3,100 miles in length. The distribution system consists of 1,472 miles of laterals, while the drainage system consists of about 112 miles of closed drains and 1,341 miles of open drains. The project also includes a small storage feature, the Senator Wash Reservoir and Pumping-Generating Plant, which can store water during times of surplus and discharge it back into the canal when needed.

Branching off the All American Canal about 12 miles west of Yuma is the Coachella Canal, which carries water northwesterly for 123 miles to the

Coachella Valley County Water District's distribution system, which administers the canal. The distribution system is largely underground, consisting of gravity flow concrete pipelines, with a few small pumping plants serving the higher areas. The network of laterals totals about 495 miles in length. The Bureau of Reclamation recently completed a project to line most of the All-American and Coachella canals, which previously lost more than 70,000 acre-feet of water each year that soaked into the sandy soils beneath the unlined-canals.

APPENDIX B: WATER TREATMENT SYSTEMS AND TECHNOLOGIES

The technologies found in water treatment facilities in California are described below.

Settlement

Settlement facilities remove sediment from the incoming supply. Settlement alone -- the process of simply allowing the water to remain still for some period of time -- provides considerable benefit, including settling of suspended solids and adsorbed substances (e.g. turbidity, heavy metals), biodegradation of organic substances, and die-off of fecal bacteria and viruses.

Coagulation

Addition of coagulants as the water enters the treatment plant forms "flocs" -- microscopic particles that attract dirt and other contaminants, eventually gaining sufficient mass that they fall to the bottom. Alum was the first chemical documented for use to help coagulate sediment, more than 3,500 years ago in Egypt, and it is still commonly used today, along with more modern polymers, such as polyaluminium chloride or PACl. (LeChevallier/Au 2004).

Filtration

Filtration systems are used to remove suspended particles and reduce turbidity. Sand, gravel and charcoal filters were commonly used in treatment facilities from as early as 1907; today's treatment facilities generally use multi-media rapid gravity filters, and are increasingly using use reverse osmosis (RO) or other types of membrane technology, in which water is pumped at high pressure through membranes that capture impurities while allowing water to pass through. (LeChevallier/Au 2004)

Membrane filtration is capable of removing very small individual particles, but requires considerable pressure to move the water through the membrane. It comes in several grades related to its porosity, from microfiltration up to RO. Use of RO filters, especially, is very energy intensive, requiring up to 100 times more pressure than ultrafiltration and microfiltration membranes, and up to five times more pressure than nanofiltration membranes (LeChevallier/Au 2004, Table 2.7).

Disinfection

Disinfection facilities include equipment that injects chlorine, ozone or chloramine into the water to kill bacteria and other microorganisms. The water generally must be stored post treatment in covered tanks while the disinfectant completes the process, with total disinfection time dependent on a combination of disinfectant concentration and contact time; the longer the time the water is exposed to the disinfectant, the lower the concentration required, and vice versa.

Disinfection is perhaps the simplest process in a given treatment plant, but is likely to become somewhat more complex because of growing concern over chlorine-resistant pathogens in drinking water that can cause illnesses, such as hepatitis, gastroenteritis, Legionnaire's Disease, and Cryptosporidiosis, and because chlorination in itself creates disinfection by-products that are regulated by the US Environmental Protection Agency.

Another type of disinfection is to expose the water to intense ultraviolet (UV) light. The exact intensity is governed by a balance of flowrate vs. lamp wattage -- greater intensity of UV light allows a higher flow rate. UV light disinfection kills microorganisms through reactions with microbial nucleic acids and is particularly effective for control of Cryptosporidium.

End User Treatment

Additional treatment in the end user's home or business is occasionally needed, either to soften the water further (remove mineral compounds), or to meet higher water grade standards, such as highly pure industrial grade water used to cool a nuclear reactor, or ultra pure reagent grade water used in chemical manufacturing and analysis processes. The additional treatment involves everything from home water softeners, to additional RO membrane filtration at industrial facilities to remove particles down to less than 1 micron in diameter. The more treatment required, the more energy required.

Additional Treatment for Wastewater

In addition to the treatment processes described above, wastewater treatment includes processes to speed the breakdown of waste. In a typical treatment process, oxidation/deodorizing chemicals are added to the raw wastewater (called influent) as it enters the treatment plant. It passes through mechanical screens that remove large debris and is then pumped to grit chambers that remove sand, gravel and metallic objects (some of these also require aeration). These facilities are usually enclosed to trap odors, which are vacuumed out by a forced-air blower and treated by a chemical or biological process to remove the offending pollutants.

The wastewater then flows into primary clarifiers, which remove floatable and settleable materials (sludge) from the liquid portion. The sludge is mechanically collected from the bottom of the tank and pumped to reactors, as is the floatable waste (scum) skimmed off the top. The remaining liquid portion flows by gravity to a biological process reactor that removes the organic content remaining in the wastewater. The wastewater then flows into secondary clarifiers, which stills the water and promotes settling of the bacterial growth from the biological process reactor, and also any solids or scum not removed during primary sedimentation. The collected sludge and scum is pumped back to the biological reactors to repeat the treatment process.

Sludge collected from the clarifiers is pumped to digesters for treatment. Bacteria thrive in the digesters, and convert sludge to an inert material (digested sludge), while producing methane gas and carbon dioxide as byproducts. This process takes about two to three weeks, sped along by heating the digesters and mixing the contents. Digested sludge is mechanically dewatered and distributed to sludge drying beds, with any liquid portion evaporated or decanted and returned back to the primary clarifier to repeat the treatment process. The sludge is tested to ensure it is safe and relatively odor free, and is can be used to fertilize non-food crops and landscaping.

APPENDIX C: EXCERPT FROM CALIFORNIA WATER PLAN UPDATE 2005

VOLUME 1, STRATEGIC PLAN, CHAPTER 2, A FRAMEWORK FOR ACTION

Sustaining Our Water Resources

Fundamental Lessons

The Framework for Action embodies the following fundamental lessons, learned by California's water community through the experience of recent decades.

- The practice of water conservation and recycling in California has grown dramatically and must continue as a fundamental strategy for all regions and individual water users in California. The cumulative effect of each decision to use water more efficiently has an enormous impact on future water supplies and water quality.
- California must protect the quality of its water and use available supplies with great efficiency because water will always be a precious resource.
- Science and technology are providing new insights into threats to our watersheds, including our waterways and groundwater basins. California must use this knowledge to take protective actions and manage water in ways that protect and restore the environment.
- Sustainable development and water use foster a strong economy, protect public health and the environment, and enhance our quality of life. Sustainable development relies on the full consideration of social, economic, and environmental issues in policy- and decision-making. Sustainable water use assures that we develop and manage our water and related resources in a way that meets the needs of the present while protecting our environment and assuring the ability to meet the needs of the future.
- Solutions to California's water management issues are best planned and carried out on a regional basis. Hydrological, demographic, geopolitical, socioeconomic, and other differences among California's regions demand that the mix of water management strategies be suited to meet each region's needs for the long term.
- California needs additional groundwater and surface water storage capacity. Storage gives water managers tremendous flexibility to meet multiple needs and provide vital reserves in drier years.

Foundational Actions

To ensure that our water resource use is sustainable, water management at all levels – State, federal, regional, and local - must achieve these three foundational actions:

1. Use water efficiently
2. Protect water quality
3. Support environmental stewardship

A number of resource management strategies that can be used to accomplish the foundational actions are listed in the following sections and described in more detail in Volume 2 Resource Management Strategies.

Use Water Efficiently

To minimize the impacts of water management on California's natural environment and ensure that our state continues to have the water supplies it needs, Californians must use water efficiently to get maximum utility from existing supplies. Californians are already leaders in water use efficiency measures such as conservation and recycling. Because competition for California's limited water resources is growing, we must continue these efforts and be innovative in our pursuit of efficiency. Water use efficiency will continue to be a primary way that we meet increased demand.

In the future, we must broaden our definition of efficient water use to include other ways of getting the most utility out of our groundwater and surface water resources and water management systems:

- Increase levels of urban and agricultural water use efficiency
- Increase recycled municipal water and expand its uses
- Reoperate water facilities to improve their operation and efficiency
- Facilitate environmentally, economically, and socially sound transfers
- Reduce and eliminate groundwater overdraft

As California's population grows from 36.5 million to a projected 48 million in 2030, there is bound to be an effect on California's environment. By wringing every bit of utility from every drop of water, Californians can stretch water supplies and help ensure continued economic and environmental health.

Protect Water Quality

California must also protect and improve water quality to safeguard public and environmental health and secure the state's water supplies for their intended uses. Water supply and water quality are inseparable in water management. While implementing projects to reduce water demand or to augment supply, water managers must employ methods and strategies that protect and improve water quality:

- Protect surface waters and aquifers from contamination
- Explore new treatment technologies for drinking water and groundwater remediation
- Match water quality to its intended uses
- Improve management of urban and agricultural runoff
- Improve watershed management

Support Environmental Stewardship

To ensure sustainability, California must also manage water in ways that protect and restore the environment. Water is a vital natural resource for people and the environment, so water management activities must occur in the context of resource management and environmental protection. Water development in California has a rich history of conflict, at times pitting water supply projects against ecosystem protection. Water supplies and the environment must both be considered together.

Water managers must support environmental stewardship as part of their management responsibilities. As managers develop and deliver reliable water supplies, environmental stewardship can be incorporated in many ways:

- Integrate ecosystem restoration with water planning and land use planning
- Restore and maintain the structure and function of aquatic ecosystems
- Minimize the alteration of ecosystems by water management actions
- Improve watershed management
- Protect public trust resources (See Box 2-2)
- Integrate flood management with water supply management

Recommendations

California Water Plan Update 2005 provides recommendations for the next 25 years. These recommendations are directed at decision-makers throughout the state(referred to as California), the executive and legislative branches of State government, and DWR and other State agencies. (See Chapter 5 Implementation Plan for details.)

1. California needs to invest in reliable, high quality, sustainable, and affordable water conservation, efficient water management, and development of water supplies to protect public health, and to maintain and improve California's economy, environment, and standard of living.

2. State government must provide incentives and assist regional and local agencies and governments and private utilities to prepare integrated resource and drought contingency plans on a watershed basis; to diversify their regional resource management strategies; and to empower them to implement their plans.

3. State government must lead an effort with local agencies and governments to inventory, evaluate, and propose management strategies to remediate the causes and effects of contaminants on surface and groundwater quality.

4. California needs to rehabilitate and maintain its aging water infrastructure, especially drinking water and sewage treatment facilities, operated by State, federal, and local entities.

5. State government must continue to provide leadership for the CALFED Bay-Delta Program to ensure continued and balanced progress on greater water supply reliability, water quality, ecosystem restoration, and levee system integrity.

6. State government needs to take the lead in water planning and management activities that: (a) regions cannot accomplish on their own, (b) the State can do more efficiently, (c) involve interregional, interstate, or international issues, or (d) have broad public benefits.

7. California needs to define and articulate the respective roles, authorities, and responsibilities of State, federal, and local agencies and governments responsible for water.

8. California needs to develop broad and realistic funding strategies that define the role of public investments for water and other water-related resource needs over the next quarter century.

9. State government should invest in research and development to help local agencies and governments implement promising water technologies more cost effectively.

10. State government should help predict and prepare for the effects of global climate change on our water resources and water management systems.

11. DWR and other State agencies should improve data, analytical tools, and information management needed to prepare, evaluate, and implement regional integrated resource plans and programs in cooperation with other federal, tribal, local, and research entities.

12. DWR and other State agencies should explicitly consider public trust values in the planning and allocation of water resources and protect public trust uses whenever feasible.

13. DWR and other State agencies should invite, encourage, and assist tribal government representatives to participate in statewide, regional, and local water planning processes and to access State funding for water projects.

14. DWR and other State agencies should encourage and assist representatives from disadvantaged communities and vulnerable populations, and the local agencies and private utilities serving them, to participate in statewide, regional, and local water planning processes and to get equal access to State funding for water projects.

APPENDIX D: ENERGY IMPACT ANALYSIS OF EXISTING WATER MANAGEMENT PRACTICES

As discussed in Chapter 4 of the Water-Energy Relationship Staff Paper, this appendix examines various water management practices, including water conservation, efficiency, and peak load reduction programs, and estimates the total effects each program would have on water and energy savings. Staff intends for this appendix to become the basis for establishing a clearinghouse of information intended to provide water industry professionals and others with comprehensive information concerning the management of energy use in the water sector. The clearinghouse will also provide information on the potential for developing additional electric generating facilities, which is examined in Chapter 2 of the Water-Energy Relationship Staff Paper, and are not examined here.

The analysis in this appendix is intended to:

- Determine policy, financial and resource implications of integrated water and energy demand-side resource planning
- Demonstrate energy efficiency imbedded in water efficiency
- Identify characteristics of joint water and energy programs, and gaps or incompatibilities in water and energy utilities' conservation programs

Structure of the Analysis

1. Implications of Integrated Resource Planning
2. Water and Energy Efficiency Program Characteristics
3. Water Efficiency Energy Use Impacts

1. Implications of Integrated Resource Planning

Significant, attainable energy savings can be realized in the form of water efficiency. Energy efficiency program sophistication, planning, implementation and evaluation are several well-funded decades ahead of water efficiency (or water conservation). Efficiency program scope and funding levels reflect varied program cost-effectiveness and regulation. Further analysis of the economically achievable water efficiency gain within the context of saving energy is needed. Such an examination will reflect major differences between water and energy in the following areas:

a. Regulatory Oversight
b. Resource Valuation
c. Technical Potential
d. Budgets (Trends)
e. Planning
f. Implementation
g. Measurement and Verification

Preliminary analysis indicates (1) a significant potential for further energy efficiency gains are achievable through water efficiency; (2) water efficiency program cost-benefit bases understate its *societal* resource value[i], and; (3) given complete avoided cost-based justification, improved cost-benefit ratios and corollary increased program funding, water-efficiency program market penetration could be significantly increased. Hence, integrated water and energy demand-side management would increase both water and energy efficiency program impacts.

2. Water and Energy Efficiency Program Characteristics

Water efficiency program measures enunciated in California Urban Water Conservation Council (CUWCC) Best Management Practices (BMP) serve as a framework to quantify the energy resource value associated with water-energy-efficiency. The BMP framework for water use efficiency explicitly includes consideration of water, wastewater, and energy, recognizing the importance of comprehensive resource management. However, as with energy utility counterparts, calculations used by water efficiency planners are based only on avoided cost of water agency operating cost bases. BMP cost-benefit methodology[ii] identifies the importance of clearly understanding the following four cost-effectiveness perspectives:

1. Program participants
2. The water utility
3. The water supply system
4. Society

Current program efficiency gain valuation is performed from the electric supply system *or* the water supply system perspective. Integrated resource planning for both water and energy must be performed from *society's* perspective to answer the question, "Which program components should receive the greater emphases?"

Using the societal perspective cancels out transfer payments between the water utility and participating customers; it also eliminates transfer payments among the water utility and other utilities. The costs that are avoided by the electric, gas, and/or wastewater utilities are viewed as societal benefits and any additional costs that are incurred by these utilities as a result of the water conservation program are societal costs.

The CUWCC was created through the Memorandum of Understanding Regarding Urban Water Conservation in California in 1991 to manage the process of implementing and updating the list of Best Management Practices (BMP) that 178 water agencies in the state have pledged to implement (see www.cuwcc.org). The current list of BMPs developed by CUWCC is below.

Best Management Practices (BMP)	Quantifiable Results
BMP 01: Water Survey Programs for Residential Customers	X
BMP 02: Residential Plumbing Retrofit	X
BMP 03: System Water Audits, Leak Detection and Repair	
BMP 04: Metering with Commodity Rates for all New Connections and Retrofit of Existing	X
BMP 05: Large Landscape Conservation Programs and Incentives	X
BMP 06: High-Efficiency Washing Machine Rebate Programs	X
BMP 07: Public Information Programs	
BMP 08: School Education Programs	
BMP 09: Conservation Programs for CII Accounts	X
BMP 09a: CII ULFT Water Savings	X
BMP 10: Wholesale Agency Assistance Programs	
BMP 11: Conservation Pricing	
BMP 12: Conservation Coordinator	
BMP 13: Water Waste Prohibition	
BMP 14: Residential ULFT Replacement Programs	X

To provide visibility to the potential impacts of integrated resource planning for water and energy efficiency programs, water sector BMPs are examined and 2004 water efficiency program results presented with societal valuation (including electric utility avoided cost). The purpose of this analysis is to combine known planning criteria from each industry to assess efficiency gain potential though programmatic integration.

Electric energy efficiency programs primarily focus on the application of electricity consuming end-use technologies at utility customer facilities. The following analysis maintains this focus but broadens the technology application scope to include systemic energy demand. For each unit of water used at a given location, an amount of energy is required. Water *energy intensity* is examined on a whole-system basis.

Water agencies are not given credit for – and do not quantify – the large energy savings (and related emissions) associated with the water saving measures implemented. Additionally, until energy efficiency regulation and policy are changed, energy-efficiency planners cannot include or target these significant energy-efficiency gains. Accordingly, neither water or energy efficiency program planners address or target these potential efficiency gains, and a significant gap exists in state-wide water and energy resource planning.

To illustrate this gap, consider BMP-6, the high-efficiency washing machine[iii] with a resource value for avoiding 5,051 gallons of water use per year over the service life of $92. Energy efficiency planners value the same measure for saving 662 kWh per year over the service life at $578. Together the combined water and energy valuation of $670, fails to capture the value the cold water energy savings (described below) of 131 kWh per over the service life valued at $127. Accordingly, the measure is under valued by approximately 20 percent. These values are only approximates as water and energy efficiency planners utilize different service life estimates as well as monetary escalation and discount rates.

Some end use energy savings have already been achieved in the water sector, but even after accounting for expectations from existing efforts in that area, an additional 30-50 percent urban water (and associated energy) savings are possible with cost-effective existing technologies. (Waste Not, Want Not: The Potential for Urban Water Conservation in California, Pacific Institute, 2004.)

End-use activities, while important, are excluded below to identify additional potential incremental efficiency gains in the remaining major areas. While electricity savings are the primary focus, future work should examine implications for natural gas consumption (including that used for electricity generation) and price. Energy used to move or process water supplies is classified in three stages: water supply (and treatment), water distribution, and wastewater treatment.

Electricity Use for Water System Components

Water System Component	**Southern California**	**Northern California[iv]**
Local Ground/Surface Water Supply	6 percent	18 percent
Imported Water Supply	71 percent	
Local Distribution	9 percent	27 percent
Wastewater Treatment	14 percent	56 percent

The following is applied as prototypical energy intensity per million gallons (MG) of water delivered, treated, distributed and disposed of in the broader Southern and Northern California:[v]

Average Water System Electricity Use ("Cold Water Energy Use")

	kWh/MG	kWh/MG *
	(SoCal)	(NorCal)
Water Supply	5,757	454
Distribution	672	686
Wastewater Treatment	2,001	2,001
Total	8,430	3,141

**Prototypical Northern California Urban Water and Wastewater Service Requirements*

The CUWCC maintains a reporting system to track reductions in water used by member agencies. The following table reflects 2004 BMP achievements for BMPs with quantifiable results:[vi]

Avoided Cost Not Included in Water Efficiency Program Valuation 2004

Northern California (PG&E/SMUD)	MG	Savings kWh (An.)	Useful Life	Life-Cycle kWh Savings	NPV Electric Avoided Cost
BMP 1 Water Survey Programs MF/SF	802	2,519,061	5	12,595,306	336,295
BMP 2 Residential Plumbing Retrofit	132	413,209	15	6,198,137	402,519
BMP 4 Metering & Commodity Rates	671	2,107,150	10	21,071,502	1,077,281
BMP 5 Large Landscape Conservation Programs	2,249	7,064,794	15	105,971,913	6,882,028
BMP 6 High-Efficiency Washing Machine Rebate	134	421,430	15	6,321,450	410,528
BMP 9 Conservation Programs CII	2,035	6,391,977	15	95,879,659	6,226,617
BMP 9a CII ULFT	109	343,115	20	6,862,300	533,184
BMP 14 Residential ULFT	5,490	17,244,882	20	344,897,646	16,798,757
Total Impact	11,621	36,505,619			$32,667,208
Southern California (SCE/LADWP/SDG&E)					
BMP 1 Water Survey Programs MF/SF	1,095	9,232,834	5	46,164,169	1,232,583
BMP 2 Residential Plumbing Retrofit	180	1,514,489	15	22,717,338	1,475,309
BMP 4 Metering & Commodity Rates	916	7,723,102	10	77,231,021	3,948,436
BMP 5 Large Landscape Conservation Programs	3,072	25,893,801	15	388,407,016	25,223,928
BMP 6 High-Efficiency Washing Machine Rebate Program	183	1,544,620	15	23,169,306	1,504,661
BMP 9 Conservation Programs CII	2,779	23,427,800	15	351,417,004	22,821,723
BMP 9a CII ULFT	149	1,257,581	20	25,151,622	1,954,218
BMP 14 Residential ULFT	7,498	63,205,741	20	1,264,114,816	61,570,608
Sub-Total		133,799,969			$119,731,468
Total Impact		170,305,588			$152,398,676

These tables reflect high variability in water conservation impacts on water related energy requirements depending upon measure location.[vii] Valuing avoided energy use by applying statewide average water intensity understates efficiency impacts and efficiency gain potential as shown below:

State-Wide Average Water Energy Intensity	kWh/MG
Water Supply	350
Distribution	1,150
Wastewater Treatment	1,200
Total	2,700

Statewide Average water Energy Instensity	MG	Savings kWh (An.)	Useful Life	Life-Cycle kWh Savings	NPV Electric Avoided Cost
BMP 1 Water Survey Programs MF/SF	1,897	5,122,182	5	25,610,911	683,811
BMP 2 Residential Plumbing Retrofit	311	840,207	15	12,603,102	818,471
BMP 4 Metering & Commodity Rates	1,587	4,284,615	10	42,846,148	2,190,509
BMP 5 Large Landscape Conservation Programs	5,320	14,365,337	15	215,480,053	13,993,706
BMP 6 High-Efficiency Washing Machine Rebate	317	856,923	15	12,853,844	834,754
BMP 9 Conservation Programs CII	4,814	12,997,251	15	194,958,771	12,661,013
BMP 9a CII ULFT	258	697,680	20	13,953,592	1,084,159
BMP 14 Residential ULFT	12,987	35,065,217	20	701,304,343	34,158,080
Total Impact	27,492	74,229,412			$66,424,503

Note the difference in resource values of $152 million for regional valuation and $66 million for statewide valuation. Statewide valuation would understate the resource value by more than 130 percent. Assessment of efficiency impacts described above for the Northern and Southern California regions is overly simplistic but serves to demonstrate the need to avoid statewide assumptions and adopt deemed savings appropriate for the given water planning regions.

The need to measure location specific water-energy-efficiency impact does not constitute a programmatic barrier for energy efficiency planners. Such treatment is consistent with current energy efficiency program planning practices. For example, all current weather dependent energy efficiency measure deemed savings reflect location specific savings across multiple climate zones (i.e., heating, ventilation and air conditioning as well as building envelope measures: insulation, window glazing, and infiltration). Therefore, adopting deemed savings for water-energy-efficiency reflecting regional water energy intensity could be readily incorporated into current energy efficiency program planning protocols. The key point is, regional variability in water energy intensity, should not defeat integrated planning. Energy efficiency planning already addresses many efficiency measures with varying deemed savings in 15 or more geographic zones.

Energy Efficiency Resource Valuation

Energy efficiency program cost-effectiveness methodology is under current and continuous review. The following avoided cost tables are currently applicable for 2004-2005 programs.[viii]

AVOIDED COST VALUES - TRC

Statewide Avg. Year	Electric Gen $/kWh	T&D $/kWh	Env.Ext. $/kWh	Total $/kWh	Year	Natural Gas Gen $/thm	T&D $/thm	Env.Ext. $/thm	Total $/thm
2004	0.05341	0.00574	0.00704	$0.07	2004	$0.34	$0.03	$0.06	$0.43
2005	0.05451	0.006	0.0072	$0.07	2005	$0.35	$0.03	$0.06	$0.44
2006	0.04961	0.0062	0.0074	$0.06	2006	$0.37	$0.03	$0.07	$0.47
2007	0.05155	0.0065	0.0076	$0.07	2007	$0.39	$0.03	$0.07	$0.49
2008	0.05325	0.00675	0.00785	$0.07	2008	$0.40	$0.04	$0.07	$0.51
2009	0.0551	0.00704	0.00814	$0.07	2009	$0.42	$0.04	$0.07	$0.53
2010	0.05708	0.00734	0.00834	$0.07	2010	$0.44	$0.04	$0.07	$0.55
2011	0.05896	0.0076	0.0086	$0.08	2011	$0.38	$0.04	$0.08	$0.50
2012	0.06138	0.00794	0.00884	$0.08	2012	$0.40	$0.04	$0.08	$0.52
2013	0.06399	0.0083	0.0091	$0.08	2013	$0.42	$0.04	$0.08	$0.54
2014	0.06676	0.0086	0.0094	$0.08	2014	$0.43	$0.04	$0.08	$0.55
2015	0.06976	0.009	0.0097	$0.09	2015	$0.45	$0.04	$0.09	$0.58
2016	0.073	0.00934	0.00994	$0.09	2016	$0.48	$0.04	$0.09	$0.61
2017	0.07649	0.00974	0.01024	$0.10	2017	$0.50	$0.04	$0.09	$0.63
2018	0.08023	0.01014	0.01054	$0.10	2018	$0.52	$0.05	$0.09	$0.66
2019	0.08428	0.01055	0.01081	$0.11	2019	$0.54	$0.05	$0.10	$0.69
2020	0.08844	0.01059	0.01108	$0.11	2020	$0.57	$0.05	$0.10	$0.72
2021	0.09287	0.01112	0.01136	$0.12	2021	$0.59	$0.05	$0.10	$0.74
2022	0.09942	0.01152	0.01167	$0.12	2022	$0.61	$0.05	$0.10	$0.76
2023	0.10222	0.01191	0.01198	$0.13	2023	$0.64	$0.06	$0.11	$0.81

3. Water and Energy Efficiency Program Characteristics

As related above, there is great variability between water and energy efficiency program targets, regulatory oversight and compliance. Targets for water conservation are referenced to a 10-year reporting period, and program participation by agencies is voluntary. Performance requirements for the BMP with quantifiable results follow:

Best Management Practices (BMP)	Requirements
BMP 01: Water Survey Programs for Single-Family and Multi-Family Residential Customers	Survey 15 percent of residential customers within 10 years
BMP 02: Residential Plumbing Retrofit	Retrofit 75 percent of residential housing constructed prior to 1992 with low-flow showerheads, toilet displacement devices, toilet flappers and faucet aerators
BMP 04: Metering with Commodity Rates for all New Connections and Retrofit of Existing	Install meters in 100 percent of existing unmetered accounts within 10 years; bill by volume of water use; assess feasibility of installing dedicated landscape meters
BMP 05: Large Landscape Conservation Programs and Incentives	Prepare water budgets for 90 percent of commercial and industrial accounts with dedicated meters; provide irrigation surveys to 15 percent of mixed-metered customers
BMP 06: High-Efficiency Washing Machine Rebate Programs	Provide cost-effective customer incentives, such as rebates, to encourage purchase of machines that use 40 percent less water per load
BMP 09: Conservation Programs for CII Accounts	Provide a water survey of 10 percent of these customers within 10 years and identify retrofitting options; OR reduce water use by an amount equal to 10 percent of the baseline use within 10 years

BMP 14: Residential ULFT Replacement Programs	Replace older toilets for residential customers at a rate equal to that of an ordinance requiring retrofit upon resale

Voluntary participation by a broad array of different water agency structures, based upon signing an MOU, with program verification and oversight performed by a non-profit organization, is vastly different than that implemented by the energy utilities under regulatory mandate.

Current Energy Efficiency Program Funding:

- $762 million allocated to 2004-2005 energy efficiency programs, increase of $245 million (43%) over statutory levels
- 2006 – 2008 Funding cycle projected at $498 million per year

Current Water Efficiency Program Funding:

- $180 million for water use efficiency programs 2003 – 2007 or $36 million per year[ix]

Because the full societal cost-based evaluation of water efficiency programs is not currently being performed, lower cost energy resources available through water efficiency are not being pursued. Without accounting for the energy related costs avoided, water efficiency programs cannot provide the scope of programmatic offerings and incentives to move the market. This treatment of water efficiency programs, and the related effect on energy resource planning, is inconsistent with the state's Energy Action Plan and fails to ensure that all cost-effective energy efficiency will be implemented as first in the loading order of actions to be under the Energy Action Plan.

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[i] An integrated water-energy *societal* total resource cost valuation would include the avoided marginal cost of water (commodity only), water related environmental externalities, and; the associated marginal cost energy (kWh), capacity (kW), transmission, distribution (including line losses) and environmental externalities. Environmental externalities related to avoiding water and energy use need to be itemized (to remove potential double-counting) and combined to reflect a composite environmental impacts.

[ii] "A Guide to Customer Incentives for Water Conservation" Prepared by Barakat and Chamberlain for CUWA, CUWCC, and US EPA, February 1994 (EPA # 230R94001)

[iii] First Partial Revision, BMP Costs & Savings, A Guide to Data and Methods for Cost-Effectiveness Analysis of Urban Water Conservation Best Management Practices, December 2003, Prepared for the CUWCC by A & N Technical Services, Inc., Appendix A-7

[v] Methodology for Analysis of Energy Intensity of California's Water Systems and An Assessment of Multiple Potentials Benefits through Integrated Water-Energy Efficiency Measures; Exploratory Research Project Supported by: Ernest Orlando Lawrence Berkeley Laboratory, California Institute for Energy Efficiency; Principle Investigator Robert Wilkinson, PhD – January 2000. (In this example NorCal system-wide Supply is estimated at 30 percent).

[vi] Data was obtained from public access CUWCC website
http://bmp.cuwcc.org/bmp/summaries/public/bmpsavings.lasso

[vii] Water conservation activity is reported by CUWCC aggregated; to support disaggregating between SoCal and NorCal, electric service customer populations were used to establish approximately 60 percent - 40 percent shares for SoCal and NorCal, respectively.

[viii] CPUC Energy Efficiency Standard Contract ATTACHMENT B3, Monthly Report Workbook, LU Avd. Costs TRC tab; discount rates for net-present-value determination is 8.5%.

[ix] Proposition 50 Chapter 7 provides $180 million for water use efficiency programs per year as follows: Urban water use efficiency $ 60. Million; Agricultural water use efficiency $60 million; Water recycling $60,000. The Bond law was passed in November 2002 and the funding will be allocated through 2007 (5-years). Proposition 13 also had funding for water use efficiency but in form of loan. DWR water use Efficiency Office funded partially through general fund estimated at less than $1 million. In addition to Statewide funding, local agencies have funding budgeted in their programs for water use efficiency programs.